



Farmed Bird Welfare Science Review

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Contents

General Introduction	11
Intro1. Purpose	11
Intro2. Structure	11
Intro3. Methodology	12
Intro3.1 Scoping review	12
Intro3.2 Full review	13
Intro3.3 Peer review	13
Intro4. Literature Included in Review	14
Intro5. Geographical Origin of Literature	16
Intro6. Relationships Between Farmed Bird Types	17
Intro7. Stocking Density and Stocking Rate	17
Intro8. Assessing Welfare	18
Intro8.1 Multiple measures	18
Intro8.2 Animal emotion	18
Intro9. References	20
Laying Hens	21
LH1. Introduction	21
LH1.1 Rearing systems	21
LH1.2 Conventional cages	21
LH1.3 Furnished (enriched or colony) cages	22
LH1.4 Non-cage systems	23
LH1.5 Free-range and organic systems	24
LH1.6 Backyard poultry	24
LH1.7 The Australian laying hen industry	24
LH2. Feed and Water	25
LH2.1 Relationship between diet, bone strength and risk of fracture	25
LH2.2 Relationship between diet and injurious pecking	25
LH2.3 Free-range and organic diets	26
LH3. Risk Management	26
LH3.1 Mortality	26
LH3.2 Causes of mortality	29
LH3.3 Bone fractures and damage	31
LH3.4 Bone strength and disuse osteoporosis	32
LH3.5 Inter-bird pecking	33
LH3.6 Relationships between feather pecking and other traits	37
LH3.7 Feather loss due to abrasion	37
LH3.8 Foot health	37
LH3.9 Eye abnormalities	38
LH3.10 Haemorrhagic fatty liver syndrome	38
LH3.11 Parasitic infections	38
LH3.12 Infectious diseases	40
LH3.13 Immune function	41
LH4. Facilities and Equipment: Behavioural Needs	41
LH4.1 Behavioural need for a nest	42
LH4.2 Behavioural need for a perch	42
LH4.3 Behavioural need to forage	44
LH4.4 Behavioural need for dust-bathing	44
LH4.5 Social behaviour	44
LH5. Facilities and Equipment: Behavioural Usage	45
LH5.1 Behaviour in conventional cages	45
LH5.2 Behaviour in furnished or colony cages	46
LH5.3 Behaviour in non-cage systems	47
LH5.4 Behaviour in free-range systems	49
LH6. Fear and Distress	50
LH6.1 Stress	50
LH6.2 Fear	50

LH7. Sensory Environment.....	51
LH7.1 Light and vision	51
LH7.2 Sound, noise and hearing	52
LH7.3 Olfaction.....	52
LH7.4 Magnetic sense.....	52
LH7.5 Thermal comfort.....	52
LH8. Handling and Management.....	53
LH8.1 Stocking density and group size.....	53
LH8.2 Air quality and biosecurity	54
LH8.3 Procedures.....	54
LH9. Rearing	58
LH10. Breed effects.....	59
LH11. Welfare Considerations: Overview.....	59
LH12. References	61
Laying Hen Breeders	90
LHB1. Introduction.....	90
LHB2. Risk Management.....	90
LHB2.1 Infectious disease	90
LHB3. Fear and Distress	90
LHB4. Welfare Considerations: Overview	90
LHB5. References	90
Broilers.....	91
B1. Introduction	91
B1.1 Commercial systems	91
B1.2 Backyard production.....	91
B1.3 Australian broiler production.....	91
B2. Feed and Water	92
B2.1 Genotypic differences in feeding behaviour	92
B2.2 Nutrition and litter quality.....	92
B2.3 Dietary restriction	92
B2.4 Mycotoxins and necrotic enteritis	93
B2.5 Dietary modifications for environmental reasons.....	93
B2.6 Probiotics.....	93
B2.7 Water supply and health.....	93
B2.8 Drinker design	94
B2.9 Measuring thirst.....	94
B2.10 Measuring water consumption.....	94
B3. Risk Management	94
B3.1 Mortality.....	94
B3.2 Metabolic disorders	96
B3.3 Leg disorders and lameness	97
B3.4 Contact dermatitis	102
B3.5 Parasitic infections	108
B3.6 Infectious disease.....	109
B3.7 Aggression	109
B4. Facilities and Equipment: Behavioural Needs.....	109
B4.1 Influence of selection.....	109
B4.2 Inactivity: morphology or absence of motivation?.....	110
B4.3 Innate hunger	110
B4.4 Behavioural need to perch	110
B5. Facilities and Equipment: Behavioural Usage.....	111
B5.1 System type.....	111
B5.2 Litter substrate.....	111
B5.3 Use of perches and elevated structures	111
B5.4 Use of vertical panels	112
B5.5 Use of other enrichment devices.....	112
B5.6 Health benefits of enrichment.....	113
B6. Facilities and Equipment: Outdoor Range.....	114
B6.1 Factors influencing range use	114

B6.2 Health and welfare benefits of range use	114
B7. Fear and Distress	115
B7.1 Fearfulness and sociality	115
B7.2 Effects of parents, incubation	115
B7.3 Fearfulness and hatchery procedures	115
B7.4 Fearfulness and human contact	115
B8. Sensory Environment	116
B8.1 Light and vision	116
B8.2 Sound, noise and hearing	119
B8.3 Olfaction	119
B8.4 Thermal comfort	119
B9. Handling and Management	121
B9.1 Stocking density and group size	121
B9.2 Air quality and biosecurity	123
B9.3 Litter quality	124
B9.4 Temperature and humidity	125
B9.5. Broiler catching	126
B10. Welfare Considerations: Overview	126
B11. References	128
Broiler Breeders	148
BB1. Introduction	148
BB2. Feed and Water	148
BB2.1 Feed restriction	148
BB2.2 Measuring hunger	150
BB2.3 Water	152
BB3. Risk Management	153
BB3.1 Mortality	153
BB3.2 Causes of mortality	153
BB3.3 Musculoskeletal disorders (lameness)	154
BB3.4 Bone strength and osteoporosis	154
BB3.5 Injurious (severe) feather pecking	154
BB3.6 Sexual aggression	155
BB3.7 Feather loss	156
BB3.8 Leg and foot health	156
BB3.9 Parasitic infections	157
BB3.10 Infectious disease	157
BB3.11 Immune function	157
BB4. Facilities and Equipment: Behavioural Needs	158
BB4.1 Behavioural need for a nest	158
BB4.2 Behavioural need to perch	158
BB4.3 Behavioural need to forage	159
BB4.4 Social behaviour	159
BB5. Facilities and Equipment: Behavioural Usage	160
BB5.1 Conventional cages	160
BB5.2 Furnished (enriched, colony) cages	160
BB5.3 Non-cage systems	160
BB5.4 Free-range systems	161
BB6. Fear and Distress	161
BB6.1 Stress	161
BB6.2 Fear	162
BB6.3 Impact upon production	162
BB7. Sensory Environment	163
BB7.1 Light and vision	163
BB7.2 Thermal comfort	163
BB8. Handling and Management	164
BB8.1 Stocking density and group size	164
BB8.2 Air quality and biosecurity	164
BB8.3 Litter quality	165
BB8.4 Procedures	165

BB9. Welfare Considerations: Overview.....	166
BB10. References	168
Ducks	173
D1. Introduction	173
D1.1 Life history.....	173
D2. Feed and Water	173
D2.1 Force feeding and foie gras production	174
D3. Risk Management.....	174
D3.1 Mortality	174
D3.2 Self-directed feather picking, injurious pecking and cannibalism	175
D3.3 Foot health	175
D3.4 Leg health	176
D3.5 Infectious disease	176
D3.6 Provision of water.....	176
D4. Facilities and Equipment: Behavioural Needs.....	178
D4.1 Behavioural need for a nest	178
D4.2 Social behaviour.....	178
D4.3 Behavioural need for water	178
D5. Facilities and Equipment: Behavioural Usage.....	179
D5.1 System type	179
D6. Fear and Distress.....	179
D7. Sensory Environment.....	180
D7.1 Light and vision	180
D7.2 Thermal comfort.....	180
D8. Management and Handling.....	180
D8.1 Stocking density	180
D8.2 Procedures.....	181
D9. Rearing	181
D10. Breed Effects	182
D11. Welfare Considerations: Overview.....	182
D12. References	183
Geese	186
G1. Introduction.....	186
G1.1 Life history.....	186
G2. Feed and Water.....	186
G2.1 Force feeding for foie gras production	186
G3. Risk Management.....	187
G3.1 Bone fractures and damage.....	187
G3.2 Parasitic infections	187
G3.3 Infectious diseases	187
G4. Facilities and Equipment: Behavioural Needs	187
G4.1 Social behaviour	187
G5. Fear and Distress	188
G6. Management and Handling.....	188
G6.1 Stocking density and group size	188
G6.2 Procedures.....	189
G7. Rearing	189
G8. Breed Effects	189
G9. Welfare Considerations: Overview.....	189
G10. References	191
Turkeys	193
T1. Introduction	193
T1.1 Life history	193
T2. Feed and Water.....	194
T2.1 Relationships with injurious pecking.....	195
T2.2 Relationship with skeletal health.....	195
T2.3 Free range and organic diets.....	196
T3. Risk Management	196
T3.1 Mortality	196

T3.2 Causes of mortality.....	196
T3.3 Musculoskeletal disorders	196
T3.4 Injurious (severe) feather pecking	197
T3.5 Aggression.....	198
T3.6 Breast blisters and breast buttons	198
T3.7 Foot pad dermatitis.....	198
T3.8 Cellulitis/clostridial dermatitis.....	200
T3.9 Eye abnormalities	200
T3.10 Parasitic infections.....	200
T3.11 Infectious diseases	201
T4. Facilities and Equipment: Behavioural Needs	201
T4.1 Behavioural need for a nest.....	201
T4.2 Behavioural need to perch.....	201
T4.3 Behavioural need to forage.....	202
T4.4 Behavioural need to dust-bathe.....	202
T4.5 Social behaviour	202
T5. Facilities and Equipment: Behavioural Usage	202
T5.1 Indoor systems	203
T5.2 Free-range systems.....	204
T6. Fear and Distress	204
T6.1 Stress	204
T6.2 Fear	204
T7. Sensory Environment.....	205
T7.1 Light and vision.....	205
T7.2 Sound, noise and hearing.....	205
T7.3 Thermal comfort	205
T8. Management and Handling	206
T8.1 Stocking density and group size	206
T8.2 Procedures	206
T9. Welfare Considerations: Overview	208
T10. References.....	209
Guinea Fowl.....	215
GF1. Introduction.....	215
GF1.1 Life history	215
GF2. Management and Handling	215
GF2.1 Stocking density and group size	215
GF3. Welfare Considerations: Overview	216
GF4. References	216
Pheasants	217
PHS1. Introduction	217
PHS1.1 Life history	217
PHS1.2 Farming and rearing.....	217
PHS2. Feed and Water	217
PHS2.1 Feeding and release.....	217
PHS2.2 Relationships with injurious pecking.....	218
PHS3. Facilities and Equipment: Behavioural Needs	218
PHS3.1 Perching	218
PHS4. Facilities and Equipment: Behavioural Usage	218
PHS4.1 Housing systems	218
PHS5. Management and Handling	219
PHS5.1 Stocking density and group size.....	219
PHS5.2 Procedures.....	219
PHS6. Welfare Considerations: Overview	221
PHS7. References.....	222
Partridges	223
PTR 1. Introduction.....	223
PTR1.1 Life history	223
PTR1.2 Farming and rearing	223
PTR2. Feed and Water.....	223

PTR2.1 Diet composition	223
PTR2.2 Food presentation	224
PTR2.3 Relationship with injurious pecking	224
PTR3. Facilities and Equipment: Behavioural Usage	225
PTR3.1 Cages	225
PTR4. Fear and Distress	225
PTR5. Sensory Environment	225
PTR5.1 Lighting	225
PTR6. Management and Handling	225
PTR6.1 Pairing and breeding group management	225
PTR6.2 Natural and artificial rearing	226
PTR6.3 Stocking density and group size	226
PTR6.4 Procedures	227
PTR7. Welfare Considerations: Overview	227
PTR8. References	228
Pigeons	230
PGN1. Introduction	230
PGN1.1 Life history	230
PGN1.2 Farming and rearing	230
PGN2. Facilities and Equipment: Behavioural Usage	230
PGN2.1 Enrichment	230
PGN3. Welfare Considerations: Overview	230
PGN4. References	231
Quail	232
Q1. Introduction	232
Q1.1 Life history	232
Q2. Risk Management	232
Q2.1 Injurious pecking	232
Q3. Facilities and Equipment: Behavioural Usage	232
Q3.1 Enriched vs barren cages	232
Q3.2 Substrate and enrichments	233
Q4. Fear and Distress	233
Q5. Sensory Environment	234
Q5.1 Lighting and vision	234
Q5.2 Thermal comfort	234
Q6. Management and Handling	234
Q6.1 Stocking density	234
Q6.2 Procedures	234
Q7. Welfare Considerations: Overview	234
Q8. References	235
Ostriches	237
OS1. Introduction	237
OS1.1 Life history	237
OS1.2 Farming and rearing	237
OS2. Feed and Water	237
OS3. Risk Management	238
OS3.1 Mortality	238
OS3.2 Causes of mortality	238
OS3.3 Bone strength, bone damage, deformities and lameness	239
OS3.4 Stomach impaction	239
OS3.5 Feather pecking and other abnormal forms of pecking	240
OS3.6 Parasitic infections	240
OS4. Facilities and Equipment: Behavioural Needs	240
OS4.1 Behavioural time budget	240
OS4.2 Foraging and ingestion	241
OS4.3 Sleep	242
OS4.4 Reproductive behaviour	242
OS5. Facilities and Equipment: Behavioural Usage	242
OS6. Fear and Distress	242

OS7. Sensory Environment	243
OS7.1 Thermal comfort	243
OS8. Management and Handling	243
OS8.1 Stocking density	243
OS8.2 Breeding group size and sex ratio	243
OS8.3 Chick groups.....	243
OS8.4 Handling	244
OS8.5 Declawing	244
OS8.6 Feather removal	245
OS9. Welfare Considerations: Overview	245
OS10. References	246
Emus	250
EM1. Introduction	250
EM1.1 Life history	250
EM1.2 Farming and rearing	250
EM2. Feed and Water	250
EM3. Risk Management	250
EM3.1 Mortality.....	250
EM3.2 Causes of mortality.....	250
EM3.3 Parasitic Infections	250
EM4. Facilities and Equipment: Behavioural Needs.....	250
EM5. Sensory Environment.....	250
EM5.1 Thermal comfort	250
EM6. Management and Handling	251
EM6.1 Declawing.....	251
EM7. Welfare Considerations: Overview	251
EM8. References.....	252
Slaughter.....	253
SL1. Introduction	253
SL2. Overview of Slaughter and Humane Killing Methods	253
SL2.1 Stunning and killing	253
SL2.2 Electrical stunning	254
SL2.3 Controlled atmosphere stunning and killing.....	260
SL2.4 Whole house killing	263
SL2.5 Low atmospheric pressure stunning.....	264
SL2.6 Percussive stunning/blunt trauma/mechanical stunning.....	265
SL2.7 Killing of surplus or unthrifty chicks	266
SL3. Farmed Birds by Type	267
SL3.1 Broilers	267
SL3.2 Laying hens	269
SL3.3 Turkeys	270
SL3.4 Ducks	271
SL3.5 Geese.....	272
SL3.6 Guinea fowl	272
SL3.7 Quail.....	273
SL3.8 Partridges.....	273
SL3.9 Pheasants	273
SL3.10 Pigeons	273
SL3.11 Ostriches	273
SL3.12 Emus	274
SL4. Welfare Considerations: Overview	274
SL5. References.....	275
Glossary.....	281
Appendix A: Literature Searches.....	288



GENERAL INTRODUCTION

INTRO1. PURPOSE

This review of the peer-reviewed scientific literature on the care, management and slaughter of farmed poultry, game birds and ratites has been prepared for the Department of Economic Development, Jobs, Transport and Resources, Victoria, Australia. The review aims to highlight scientific knowledge, where it exists, on the animal welfare consequences of care, management and slaughter procedures and practices and to identify substantial gaps in scientific knowledge.

INTRO2. STRUCTURE

The review has a structure adapted from Part A General Standards and Guidelines of the proposed draft Australian Animal Welfare Standards and Guidelines for Poultry. The adaptations that we have made are listed in Table Intro 1.

Table Intro 1: Review structure

Structure of Part A General Standards and Guidelines of the proposed draft Australian Animal Welfare Standards and Guidelines for Poultry	Structure adopted within this review for each farmed bird type
Responsibilities (human responsibilities and competences)	Impact of human contact on welfare is briefly mentioned in sections on Fear and Distress, and Handling and Management.
Feed and Water	Yes
Risk Management (including weather, fires, floods, disease, injury and predation)	Yes – the scientific literature mostly concerns disease, injury, predation, and injurious behaviour. We found no peer-reviewed literature on steps that should be taken to cope with natural disasters and emergencies.
Facilities and Equipment (included within this is the statement that facility construction should take account of poultry behaviour)	Yes – the large literature on the evidence relating to behavioural needs of some of the farmed bird species has been included in the section called Facilities and Equipment: Behavioural Needs.
Management of outdoor systems	We have included a broader section called Facilities and Equipment: Behavioural Usage. This section outlines how housing systems, and design features within housing systems (including the outdoor range), affect bird welfare.
Facilities and Equipment (included within this is the statement that facility construction should minimise fear and distress)	We have included a section on Fear and Distress.
Lighting	We have a section on Sensory Environment which covers scientific work on birds' perceptual abilities and their preferences for aspects of lighting, sound, olfaction and thermal environment.
Temperature and Ventilation	Thermal comfort aspects are included in the section on Sensory Environment. Air quality aspects (as relating to bird health) are included in Management and Handling section below.
Litter Management	The importance of good litter management in mediating risks for health or injurious behaviour is considered within the Risk Management section.
Handling and husbandry (including stocking density and procedures such as beak trimming and forced moulting)	Our section heading is Handling and Management and includes sub-sections on stocking density, whole-house management (e.g. ventilation) and procedures.
Humane Killing, and Poultry at Slaughtering Establishments	These are provided in the chapter titled Slaughter.

Scientific studies on bird welfare have been conducted for many different reasons. They do not all fit easily into any one classification system. For example, a study on the effect of perches on foot condition could be included under the section on risk management (foot health) or facilities and equipment (behavioural usage). If the use of the perches was also influenced by the light intensity then the same study might need to be mentioned under Sensory Environment, alongside other studies that examined light intensity effects on other bird welfare parameters. Whilst we have attempted to minimise repetition and cross-referencing, we consider there is no one report structure that could eliminate the need for this.

An extensive literature is available for some types of farmed birds (laying hens, broilers, broiler breeders) but there are gaps in the literature available for other types of bird. Where a section is not included (e.g. no section on Facilities and Equipment: Behavioural Needs for pigeons) this means that no welfare-relevant peer-reviewed literature was found, not that this may not be an important aspect of bird welfare.

A review of the literature on the transport of farmed birds was not required for this review. Transport of poultry is covered by the Australian Animal Welfare Standards and Guidelines – Land Transport of Livestock (2012).

INTRO3. METHODOLOGY

Intro3.1 Scoping review

To ensure a comprehensive review we consulted with librarians and selected Web of Science (WoS) as the primary database to be used. Tests showed that all papers detected in CAB Abstracts were also detected in WoS, but that WoS identified additional relevant papers.

Primary searches were then conducted using the species/type name (or variants of) and the term “welfare”. The primary search for each type of farmed bird has been fully documented, including numbers of papers excluded from further consideration and reasons for exclusion (Appendix A). To reduce the frequency of irrelevant hits we used the WoS SCI-Expanded database only, excluding other databases by using the “More Settings” function, and excluding reviews, book reviews, proceedings and editorial material. The primary search was restricted to the years 2000-2017, although the final review contains reference to older papers either if these are seminal works or (for some types of birds) if recent literature was so sparse that older literature had to be consulted.

We then conducted a series of secondary searches using the species/farmed bird type name that had the greatest utility in the primary search and combining it with key terms in the following order:

Health

Stress* or fear*

Injur* or Cull* or Mortali*

Density or space

Litter or perch* or nest* or enrich*

Dust-bath* or dustbath*

Peck* or beak*

This was followed by searches using the term well-being, and any other terms that were particularly relevant for a given type of farmed bird.

For bird slaughter, a similar approach was adopted, but the search terms varied. Species terms were as used above but no distinction was made between the various types of chicken. Chicken was searched between 2000 and 2017 and acceptances restricted to articles. Duck, geese and turkeys, ostrich and emu were searched between 2000 and 2017 and acceptances not restricted to articles. Guinea fowl, partridge, pheasants, pigeons and quail were searched between 1990 and 2017 and acceptances not restricted to articles. Searches (species AND subject AND interest) were conducted using the following terms:

Subject: ((Stun* Not stunt) OR kill* OR slaughter* OR cull* OR shackl* OR lairage OR CAS OR CAK OR “carbon dioxide” OR CO2 OR “controlled atmos” OR “Low atmos” OR laps OR waterbath OR “water-bath” OR “water bath”) NOT campylobacter

Interest: EEG or electroencephalo* or unconscious* or *insensib* or welfare or stress or pain

We then consulted every paper and excluded those that were not relevant (Appendix A).

Table Intro 2: Summary of articles available for review (excluding slaughter) for each type of farmed bird

Farmed bird type	Primary search		Secondary search	Total number of papers for review
	Papers retained	Papers excluded	Additional papers retained	
Laying hens	350	545	142	492
Laying breeders	1	13	3	4
Broilers	253	657	184	437
Broiler breeders	47	61	32	79
Ducks	32	28	24	56
Geese	2	13	7	9
Turkeys	24	169	62	86
Guinea fowl	0	4	4	4
Pheasants	3	5	7	10
Partridges	5	3	25	30
Pigeons	0	23	4	4
Quail	18	61	3	21
Ostriches	9	16	24	33
Emus	1	6	2	3

Table Intro 3: Summary of articles available for review on the slaughter of each type of farmed bird

Farmed bird type	Primary search		Total number of papers for review
	Papers returned	Papers excluded	
Chickens (encompassing laying and meat chickens and breeders)	623	543	80
Ducks	30	20	10
Geese	12	11	1
Turkeys	141	119	22
Guinea fowl, pheasants, partridges, pigeons and quail	26	24	2
Ostriches and emus	19	18	1

This exercise ensured that we initiated the review in a way that minimised source material selection bias.

Intro3.2 Full review

During the full review, the retained papers were consulted in detail. A small number of further exclusions were made whilst some additional papers were included (detected using citations of papers in our initial scoping review). For species with a small recent peer-reviewed literature some older papers or technical reports have been cited. Occasionally, and only for species with a sparse peer-reviewed literature, we mention information obtained from an abstract where the full text was not available to us (with University of Bristol access rights) within the time available. We have indicated where this was the case.

Intro3.3 Peer review

The review was subject to a peer review process, in which two independent peer reviewers with relevant expertise were provided with a comprehensive draft of the review for comment. This was a 'double blind' peer review process, in which neither we nor the reviewers were aware of each other's identity. The process was facilitated by the agency that commissioned the review, the Department of Economic Development, Jobs, Transport and Resources, Victoria, Australia. Each peer reviewer provided a report with their comments, which assisted in finalising the review.

INTRO4. LITERATURE INCLUDED IN REVIEW

Laying Hens

Total references: 582 (600 after review)

53 of 492 original references (Table Intro 2) were not used (conference papers, duplicates or substandard). During the writing phase 143 new references were added, including key older works, and papers on the topic of moulting. Overall, we found an extensive peer-reviewed literature available. The length of each section in our review reflects the scientific literature available. Some issues have been well-studied because of their accessibility or because they raise theoretically interesting or complex questions (e.g. the behavioural needs of laying hens), whereas other potentially impactful issues remain relatively unstudied. An additional 18 references were included at post-review revision.

Laying Hen Breeders

Total references: 2

2 of the 4 original references (Table Intro 2) were not used. No useful new references were detected during the writing phase. The literature on layer breeders is virtually non-existent largely due to the high security facilities within which these birds are kept, making them inaccessible to independent scientific study.

Broilers

Total references: 386 (401 after review)

115 original references (Table Intro 2) were not used (34 were conference papers, 8 were duplicates, 73 substandard). 64 new references were added including key older works. An additional 15 references were included at post-review revision.

Broiler Breeders

Total references: 84

27 original references (Table Intro 2) were not used (conference papers, or related to egg and embryo quality). 32 new papers were added during the writing phase including key older works.

Ducks

Total references: 70

Of the 56 original references (Table Intro 2), 7 were excluded and an additional 21 references were added during the writing phase (mainly older research papers and two reviews).

Geese

Total references: 39 (40 after review)

2 of the 9 original references were excluded (Table Intro 2) as not relevant to welfare, and an additional 32 references were added during the writing phase (reviews, older articles and articles providing information about the natural behaviour of geese). Reference to a European Food Safety Authority (EFSA) report was added at post-review revision.

Turkeys

Total references: 101 (108 after review)

7 of the original references (Table Intro 2) were excluded and an additional 22 references were added during the writing phase. The majority of primary research literature on turkey welfare focuses on the growing poults, with very little reference to the breeder birds. An additional 7 references were added at post-review revision.

Guinea Fowl

Total references: 8

All 4 original references were used (Table Intro 2) and 4 additional references were added during the writing phase.

Pheasants

Total references: 19

2 of the original references (Table Intro 2) were excluded and 11 additional references were added during the writing phase.

Partridges

Total references: 28 (29 after review)

6 of the original references (Table Intro 2) were excluded and 3 additional references were added during the writing phase. One additional reference on post-release survival was added at post-review revision.

Pigeons

Total references: 10 (12 after review).

All 4 original references (Table Intro 2) were used and an additional 6 references relating to pigeon natural biology were added during the writing phase. Scientific literature relating to captive pigeons is mainly focused on their spatial understanding and navigation abilities, memory, learning and cognition. There were no papers found in the search that investigated the welfare of common husbandry practices for pigeons. Therefore, it is suggested that referring to the literature of pigeon natural biology and habitat should be used to inform husbandry guidance. An additional 2 references were added at post-review revision.

Quail

Total references: 23 (30 after review)

None of the original references (Table Intro 2) was excluded and 2 new references relating to quail natural biology were added during the writing phase. Papers on quail mostly report fundamental experimental studies of stress biology. Some welfare-relevant information about stressors and ways to ameliorate stress in quail can be gained from these papers. Those that related to commercial quail keeping tended to focus on production traits with only a few detailing welfare parameters. These studies were laboratory replicas of commercial conditions. No papers reporting on the welfare of commercial quail farms were retrieved. An additional 7 older references were added at post-review revision.

Ostriches

Total references: 68 (69 after review)

All of the original 33 references (Table Intro 2) were used (although many were of lower standard in terms of replication, control, study power, hypothesis than those included for sections on chickens). An additional 35 references were added during the writing phase. This included older papers (there was a phase of increased interest in ostrich farming in the 1990s) and some technical reports for sections where peer-reviewed literature was absent. We are also aware of articles and book chapters that address ostrich welfare e.g. *Brand, T. and Olivier, A., 2011. Ostrich Nutrition and Welfare. In: P.C. Glatz, C. Lunam and I. Malecki (Eds.), The Welfare of Farmed Ratites, (Berlin, Heidelberg, Germany: Springer-Verlag), pages 91–109.* We have not consulted these, but there may be much practical knowledge within these texts. Standards for keeping ostriches have also been published (e.g. Council of Europe, 1997). Overall, because of the sparse literature and because practices and breeds may have changed over time, an overview of the welfare considerations for ostriches is less complete than that for chickens. One paper describing husbandry systems was added at post-review revision.

Emus

Total references: 10

Three original references (Table Intro 2) were used, and 7 were added during the writing phase. Comments for ostriches (above) apply to emus. We found some management guides and technical reports available on various websites but virtually no peer-reviewed scientific papers or controlled trials on emu management, husbandry or welfare.

Slaughter

Total references: 105 (115 after review)

There is an extensive published and peer reviewed scientific literature covering the welfare aspects of chickens at slaughter (broiler and laying hens). Significantly less work is published on ducks, geese and turkeys, ostrich and emus, and almost none focusing on partridge, pigeon, quail, pheasant or guinea fowl. An additional 10 references were added at post-review revision.

INTRO5. GEOGRAPHICAL ORIGIN OF LITERATURE

The scoping review methodology protects against unintentional bias in selection of papers for inclusion in the review. The papers that have been included come primarily from Europe and Northern America (USA and Canada). An example of a distribution of papers by country of origin is presented in Table Intro 4, showing a breakdown for the laying hen primary search. The percentages add to more than 100% reflecting the fact that given papers can have authors from different countries. This shows that 85% of the literature comprised studies that either originated in Europe, or included an input from European authors; 14.6% had an input from the USA, 6.4% an input from Canada and 6.1% an input from Australia. Table Intro 5 shows the breakdown for the ostrich primary and secondary searches showing a predominance of papers from South Africa.

In reading the review it should be acknowledged that factors relating to the Australian climate, environment and established management practices may not be fully represented in the literature.

Table Intro 4: Country of origin of papers resulting from primary literature search for laying hens (*hen* NOT hence* OR "domestic fowl"*) AND welfare, followed by initial exclusions = 350 references (Table Intro 2)


































Field: Countries/Territories	Record Count	% of 350	Bar Chart
ENGLAND	47	13.43%	
USA	36	10.29%	
GERMANY	37	10.57%	
SOUTH AFRICA	51	14.57%	
SPAIN	29	8.29%	
NETHERLANDS	23	6.57%	
AUSTRALIA	22	6.29%	
NEW ZEALAND	10	2.86%	
FRANCE	16	4.57%	
SCOTLAND	40	11.43%	
SCOTLAND/ENGLAND	15	4.29%	
UNITED KINGDOM	15	4.29%	
IRELAND	10	2.86%	
IRELAND/ENGLAND	10	2.86%	
SCOTLAND/IRELAND	11	3.14%	
IRELAND/SCOTLAND	10	2.86%	
ENGLAND/SCOTLAND	7	1.99%	
NETHERLANDS	7	1.99%	
NETHERLANDS/ENGLAND	7	1.99%	
NETHERLANDS/SCOTLAND	6	1.71%	
NETHERLANDS/IRELAND	3	0.86%	
NETHERLANDS/SCOTLAND/IRELAND	4	1.14%	
NETHERLANDS/SCOTLAND/IRELAND/ENGLAND	6	1.71%	
NETHERLANDS/SCOTLAND/IRELAND/ENGLAND/USA	1	0.29%	
NETHERLANDS/SCOTLAND/IRELAND/ENGLAND/USA/AUSTRALIA	1	0.29%	

Table Intro 5: Results of ostrich primary and secondary literature searches

Field: Countries/Territories	Record Count	% of 33	Bar Chart
SOUTH AFRICA	8	24.24%	
ENGLAND	7	21.21%	
AUSTRALIA	3	9.09%	
CANADA	3	9.09%	
POLAND	3	9.09%	
TURKEY	3	9.09%	
EGYPT	2	6.06%	
GERMANY	2	6.06%	

INTRO6. RELATIONSHIPS BETWEEN FARMED BIRD TYPES

Because of the extensive literature on the domestic chicken and relative scarcity of literature on some of the other farmed bird types, it is important to consider whether any of the results from chickens could be generalised. This will be more likely if the other bird types are closely related (phylogenetically) and share a similar ecological niche and life history.

Avian phylogenetics has advanced recently and, although still subject to some revision as new data become available, the prevailing current view (Crowe et al., 2006; Prum et al., 2015) is presented in Figure Intro 1. This suggests many common features between chickens and other game birds and some common features shared more distantly with ducks and geese, all of which are placed in the high taxon Galloanserae. Ostriches and emus are placed within a different higher taxon, the Paleognathae, as they possess more reptilian features. Of the farmed bird species under consideration in this review, only the pigeon is placed within the higher taxon, the Neoaves.

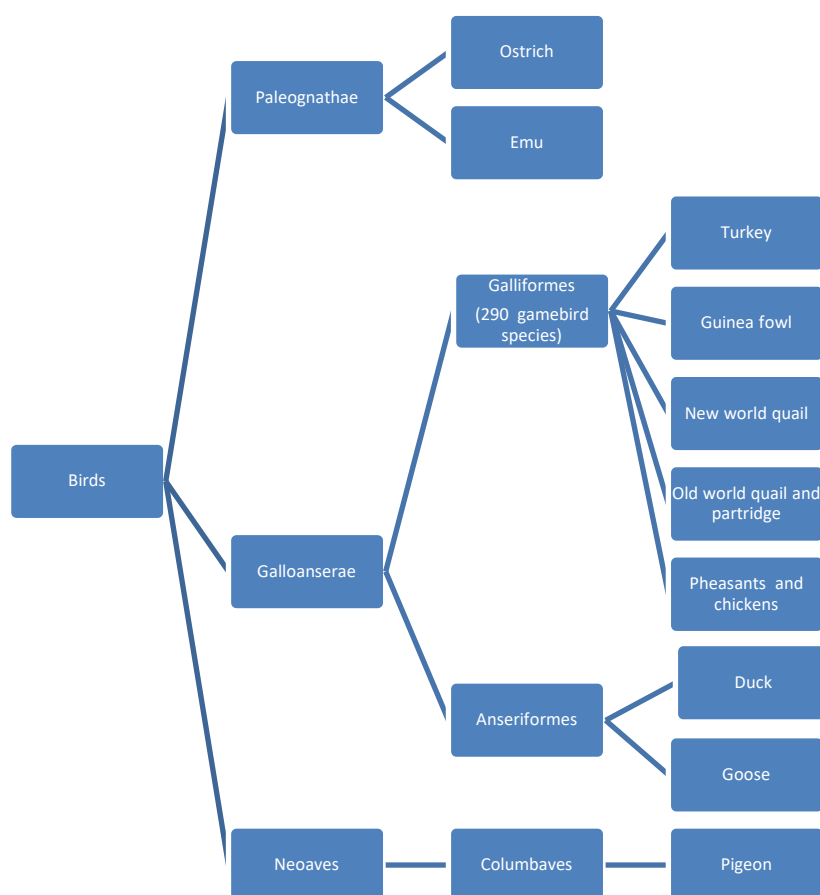


Figure Intro 1: Phylogenetic relationships between farmed bird species

Comments on ecological habitat and life histories are provided in the introduction to each farmed bird type to assist in understanding how far work on chickens can be generalised to these other species.

INTRO7. STOCKING DENSITY AND STOCKING RATE

The term stocking density is frequently found in the literature on poultry welfare as a 'catch-all' term to describe both the number of animals per unit area and the weight of animals per unit area. A distinction is drawn by some authors who use the alternative term 'stocking rate' to describe the number of birds per unit area, and reserve the term 'stocking density' to describe the weight of birds per unit area. However there is no great consistency in this usage. The number of birds per unit area is the usual unit used for laying and breeding birds which gain weight relatively slowly or which have a stable adult weight. The weight per unit area is more often used for birds that gain weight very rapidly such as broilers and turkeys, and where the size of the birds can become a limiting factor for healthy birds and environmental (air, litter) quality.

The stocking rate of caged birds (e.g. laying hens) is generally described as a space allowance expressed as cm²/bird. In contrast, the stocking rate for non-cage birds is generally described as the number of birds/m². In making rapid comparisons it should be noted that 1 m² = 10,000 cm². Thus caged birds housed at 500 cm²/bird are stocked at an equivalent rate of 20 birds/m², whilst the usual furnished (colony) cage allowance of 750 cm²/bird equates to 13.3 birds/m². The EU stocking rate for non-cage systems is 9 birds/m².

Calculating stocking densities for broiler chickens, turkeys or other meat birds requires knowledge of their expected patterns of weight gain. These are generally published openly in breed management guides e.g.:

http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-308-Broiler-PO-2014-EN.pdf

This shows that male birds of this breed would be expected to weigh 2.39 kg at 36 days of age, and 3.02 kg at 42 days of age. A stocking density of 33 kg/m² equates to 13.8 birds/m² at 36 days, and 10.9 birds/m² at 42 days. One response to maximum stocking density legislation is to “thin” flocks by removing some birds for early slaughter and leaving the others to grow further.

In this review, the generic term stocking density is used in headings and subheadings for all types of farmed birds but we then use the term stocking rate for laying hens and breeding birds, and the term stocking density for birds grown for meat.

INTRO8. ASSESSING WELFARE

The animal welfare assessment framework developed by Green and Mellor (2011) mentioned within the Proposed Draft Australian Animal Welfare Standards and Guidelines for Poultry reflects three predominant ideas that have developed over time as animal welfare has matured as a subject area. First, it acknowledges that animal welfare has many components (considered as specific domains by Green and Mellor, 2011), each of which requires consideration in order to enable a holistic picture of overall welfare (see also Mason and Mendl, 1993 who explain why there is no one, simple measure of welfare). Second, it draws attention to the importance of considering the animals’ negative and positive experiences in relation to each domain. Third, it acknowledges that challenges to animal welfare can be brief and transient or chronic and long-lasting, reducing overall quality of life.

Intro8.1 Multiple measures

In interpreting the available literature it is important to be aware that single-measure studies can be useful (e.g. plumage damage is a reasonably good measure of feather pecking) but single measures are not good indicators of overall welfare. For example, in assessing the welfare implications of toe removal, it is relevant to know whether or not neuromas (trauma-induced nerve cell growths) develop, because these can be associated with chronic pain once the original injury has healed. If no neuromas are found this would be evidence that toe amputation has not led to this type of chronic pain. However, it would not be acceptable to conclude from this one line of evidence that there was no overall welfare impact of toe amputation. A full assessment of the effect of toe removal would require studies of the birds’ initial acute responses (fear, stress, pain), other studies of chronic pain (e.g. hyperalgesia) and studies of short- and long-term behavioural consequences and impact. Where available these different strands of evidence must be considered together, and this is most easily done for those conditions that have been extensively studied (e.g. lameness in broiler chickens). Where only isolated studies are available, the extent to which generalisation is possible must be considered.

Studies of farmed bird welfare are now far more likely to incorporate multiple measures than in the past but this has not solved all the problems. For example, some measures cluster together (Nicol et al., 2011; Daigle and Seigford, 2014) so there is a risk of over-estimation from redundant information in some studies. A greater problem arises if measures do not covary in a consistent manner across differing housing or husbandry conditions.

Intro8.2 Animal emotion

Another recent development in animal welfare science has been to recognise the importance of animal emotion, and specifically the importance of animals’ positive and negative experiences (called valence) (Nicol et al., 2009; Mendl et al., 2010; Hemsworth et al., 2015; Mellor and Beausoleil, 2015; Campbell et al., 2016). Mendl et al. (2010) portray human emotion within a simple two-dimensional model (Figure Intro 2) and discuss how this can be applied to animals.

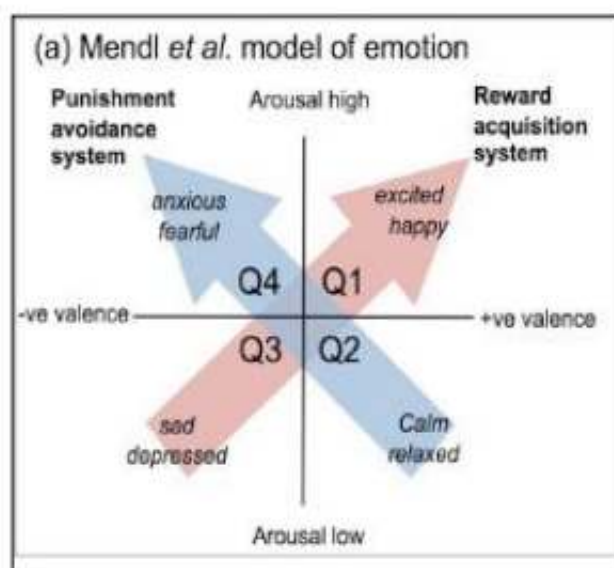


Fig Intro 2: Two dimensional model of animal emotion

Although the words “sad” or “happy” are useful shorthand terms for human emotional experience, they cannot be used to describe animal emotions as the subjective nature of animal experience cannot be known. However, an animal’s experience can be mapped within these quadrants and current work is assessing which physiological and other measures provide the best markers of these experiences (e.g. Nicol *et al.*, 2009).

Some measures are clearly related to pain or fearfulness and are good markers of negative valence and hence poor welfare. But other measures (particularly those associated with physiological stress) appear now to be better measures of arousal or excitement than of valence (Mendl *et al.*, 2010). In addition, all animals have evolved to experience and respond to stressors; so that some degree of intermittent stress or challenge is likely to be positive and healthy. As with humans, the extent to which an animal can control its environment may well determine the extent of its stress response. Measures of stress are still immensely useful, especially in quantifying the impact of procedures known to be aversive (e.g. stress associated with rough handling) but they are less useful in assessing complex scenarios where information on valence is less clear (e.g. comparing one housing system with another).

In this report we use the terms ‘measures’ or ‘markers’ to describe experimental outcomes recorded in a scientific paper that may have some bearing on animal welfare, and the term ‘welfare indicator’ where there is a stronger evidence base.

The integration of information from multiple measures, and its interpretation in terms of animal perception and emotion is currently undertaken by seeking expert opinion. We have made our best ‘expert’ judgements in writing brief overviews of the welfare considerations for each of the farmed bird species.

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LAYING HENS

LH1. INTRODUCTION

Laying hens are a specialised group of domesticated chickens. Chickens were first domesticated in Southeast Asia, with multiple origins from different Asian Red Junglefowl subspecies. Chickens were probably not kept at first for their eggs, but in the late 19th and early 20th century divergent selection for meat and egg-laying strains heralded the appearance of modern meat (broiler) and layer strains, with bodily resources primarily allocated either to growth or reproduction. Modern strains of laying hens can be housed in a wide variety of systems. These are briefly described here.

LH1.1 Rearing systems

Pullets destined for egg production can be reared in cage or in non-cage systems. Rearing cages generally provide no enrichment, and differ from conventional cages mainly in having a flat rather than a sloping floor. By the end of the growing period, birds are tightly stocked at space allowances of approximately 300 cm²/bird. Cage systems are the most commonly used rearing method in many countries of the world but problems can arise if cage-reared birds are moved to non-cage systems (Janczak and Riber, 2015). In Europe, many pullets are reared in non-cage systems, most commonly in floor systems (as for broilers). Until recently, floor systems did not provide any tiers or perches. Practice is now changing as it is increasingly appreciated that experience with such furniture can help ease the transition between rearing and laying environments and reduce problems such as smothering, floor laying and injurious pecking (Janczak and Riber, 2015; see also section LH5.3). More recently, fully tiered rearing aviaries have been developed. In these systems, day-old chicks are confined for the first few weeks of life in warm central and lower tiers, then released at approximately 4 weeks of age to move freely within the aviary system and make use of a littered floor area.

LH1.2 Conventional cages (CC)

This system developed in the middle of the last century to reduce contact of the bird with its faeces and thereby improve hygiene and reduce parasitic diseases and mortality. It largely replaced mobile housing where both birds and stockmen were often exposed to cold, wet, muddy conditions. Initially cages housed birds singly and were often simple wire and wooden structures of the type which may still be found today in China, Africa and Asia in particular. Now, 3-6 birds per cage and vertical or sloping tiers up to 7 or 8 high are usual with tens of thousands of birds per house commonplace. Over time, to reduce costs, cage sizes decreased and number of hens per cage increased. A minimum legal space allowance of 450 cm² per bird was prescribed within the European Community (EC) in 1988. In 1999 the EC specified (1999/74/EC) minimum space allowances in cages of 550 cm² per hen of unrestricted area from 2003-2012, after which the system was banned. This minimum space allowance currently applies in Victoria and other states in Australia. Conventional cages are now being phased out in New Zealand (by 2022). As of 1 April 2017, no new conventional cages will be constructed in Canada, with a 15 year phase-out period. In the USA a wave of restaurants, supermarkets and other retailers (representing some 70% of US egg production) have committed to go cage-free within 10 years, a move that is taking place alongside individual bans on conventional cages in some states (California, Michigan, Oregon). Countries such as Taiwan have published guidance designed to encourage a voluntary switch from conventional cage production.

In the USA, standard industry practice was to house birds at just 340 cm² per bird, until a 2001 recommendation by the United Egg Producers led to an increase of space to 67 to 86 in² (430 to 560 cm²) per bird. In many other countries, space allowances of less than 400 cm² per bird are still commonly applied (see Section LH8.1).

A typical cage size is 0.45 m from front to back and in front height, reducing to 0.35-0.38 m at the rear. Welded wire mesh flooring 2.5 x 5.0 cm is standard. Intensive conventional cages systems are fully automated, with each tier having: lines of nipple drinkers filled by mains water via a small tank with a ball valve, a continuous feed trough in front of the cages with feed distributed via augers and chain distribution from large external feed silos; belt collection of eggs that roll onto it, to be conveyed for grading and packing which can also be highly automated, and manure removal via belts under the cages to a deep pit under the house or to a separate room. A controlled environment enables optimum feed conversion efficiency. The cages are very seldom uniformly lit, with birds in lower tiers experiencing very dim conditions, whereas those nearer the light sources experience higher light levels. A row of lightbulbs above human head height is the most common form of lighting but both horizontal and vertical fluorescent tube lighting is also seen.

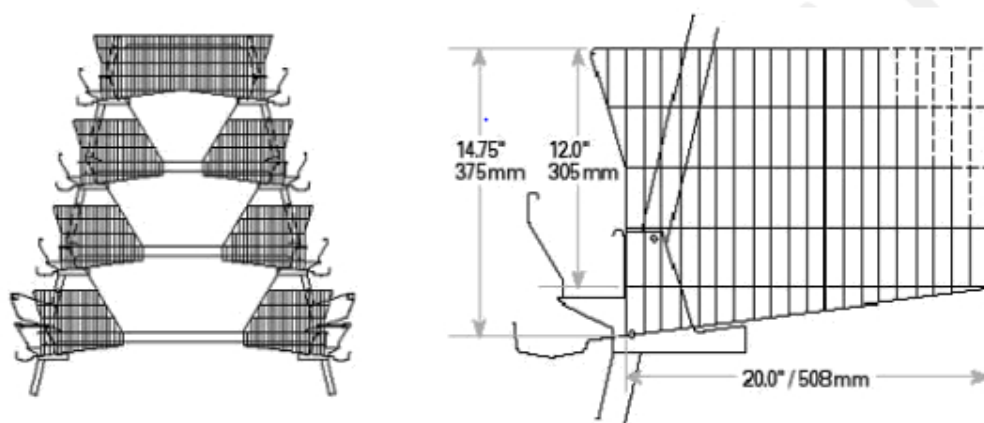


Figure LH1: Example of a Conventional Cage (dimensions vary) (from www.laywel.eu)

LH1.3 Furnished (enriched or colony) cages (FC)

Furnished cages were designed with the express purpose of improving hen welfare. The first commercial-scale trials of furnished cages examined the performance and welfare of hens housed in groups of 4 to 8 birds, at spatial allowances of between 470 cm² to 875 cm²/bird (Appleby et al., 2002). Commercial manufacturers began to produce cage systems compliant with the European Union (EU) Directive (750 cm²/bird, nest, perch and foraging facilities provided) but economic pressures led them to produce cages for 20, 40, 60 or 80 birds. A distinction between large (LFC) or colony cages and smaller furnished cages (SFC) is sometimes made. The reduction in capital cost for farmers wanting to invest in a new system prevailed, and furnished cages for larger groups of hens became known as colony cages. These now predominate in the EU.

For practical and hygienic purposes, commercial designs provide a plastic artificial turf 'scratching' area, where food can optionally be scattered to encourage foraging and dust-bathing. Perch height and orientation (parallel with the feed trough or at right angles and often both in a T configuration) varies considerably, with metal and plastic being common materials. Floors of most furnished cages are wire and sloped, as in conventional cages, to enable easier collection of any floor eggs, but there is no other reason precluding them from being level. All cages provide a nesting area which may have a plastic mesh or an artificial turf floor to enable hens to perform some manipulation behaviour and to have a more comfortable and defined surface than the wire floor on which to lay. These nesting areas are defined by strips of plastic suspended from the roof of the cage and are often coloured and opaque to enable the hens to have a sense of enclosure. As for conventional cages, feed troughs are placed outside the cage at the front.

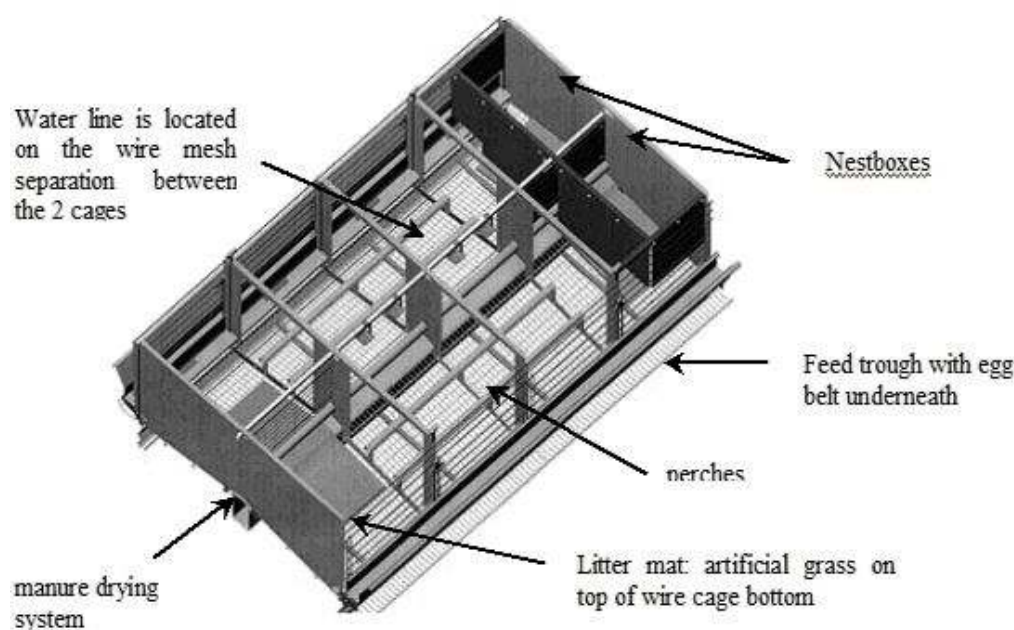


Figure LH2: Example of a Furnished Cage (from www.laywel.eu)

LH1.4 Non-cage systems (NC)

Barns are non-cage systems that contain up to tens of thousands of hens, although these are often subdivided into smaller colonies (e.g. of 4,000 birds) with simple, netting barriers to aid management or to meet the requirements of assurance schemes. The EU Directive 1999/74 requires all barn systems in member states to provide a minimum 250 cm² littered area per hen, with stocking rate not to exceed 9 hens/m² useable area. Each hen must also be provided with 15 cm of perch and 10 cm each of feeder and drinker space.

LH1.4a Single-tier barn (ST)

One of the simplest forms of housing, this can range from straightforward roofed barns with open sides that confine the birds with netting or natural materials in tropical climates to large, insulated barns with controlled environment incorporating fans. It can be described as straw-yard or deep litter. Most commonly there is a central, raised area (the single tier) which is slatted and above which the feeder and drinker lines run; nestboxes are usually placed back to back, centrally, with automated collection of eggs via egg-belts running underneath them. Hens may roost directly on the slats or be provided with additional aerial perches. Droppings are usually cleared frequently using scrapers or manure belts but deep pits for manure are also used. The rest of the floor has some form of substrate such as wood shavings, straw or rice hulls in which the droppings accumulate to form a deep litter. It is extremely important for this to be kept friable to enable foraging behaviour and reduce the incidence of injurious pecking. The maximum stocking rate for eggs to be described as barn (deep litter) is 7 birds per m² under EC trading standards.

A variant of the single-tier barn system is the slatted or wire floor system, which reduces contact between birds and their faeces. The system is not widely used, largely because multi-tier systems are becoming more common.

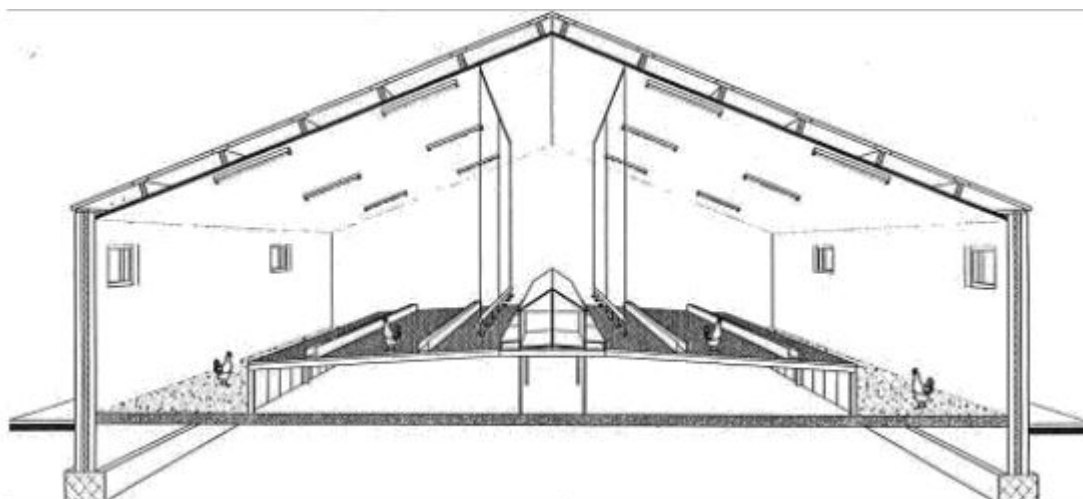


Figure LH3: Example of a Single-Tier Barn (from www.laywel.eu)

LH1.4b Multi-tier barn or aviary (MT)

A wide range of designs are now produced by commercial manufacturers for systems that provide multiple tiers for loose-housed hens. These make use of the vertical space within a house and enable a greater number of birds to be kept on the house footprint. In cooler climates the extra heat generated from more birds allows air temperature to be maintained close to the thermoneutral zone. In theory, the birds have a greater choice of resources and the option to escape bullies by moving to another level. An option being considered by some US producers is to provide colony cages with removable fronts.

EC rules specify at least 0.025 m² of littered area per hen with at least one third of the floor area being litter (1999/74/EC). In the EU up to 25 birds/m² are permitted in MT units with a minimum of 15 cm of perch space per bird. A popular aviary system comprises modules of double tiers (2 raised levels) with feed, water, lighting and perches on every level with separate banks of nestboxes offering flexible layout and easy bird inspection. This can also be adapted to incorporate nestboxes within the tiers and to give birds access from both sides of the nests. It is generally simple to manage and depopulate and ideal for low-roofed housing but does not maximise production per unit floor area. The company marketing the Boleg terrace aviary claims its open design is like a tree, facilitating vertical movement by hens. It comprises banks of 4 tiers with nestboxes on the second level up from the floor, and the upper tier devoted to perching. Manure belts remove droppings from levels 1 and 3. Portal aviary systems comprise two multi-tiered stacks containing feed, water and nests with a top tier extending right across the top of both of them and the wide, central littered area or portal. This central area is above head height and often accessible by vehicles such as bobcats thus facilitating litter management during the

laying period. The litter extends under the stacks over the whole ground floor. There is variation in design and layout but they are generally suited only for both wide and tall houses (e.g. >12 m and >3 m respectively).

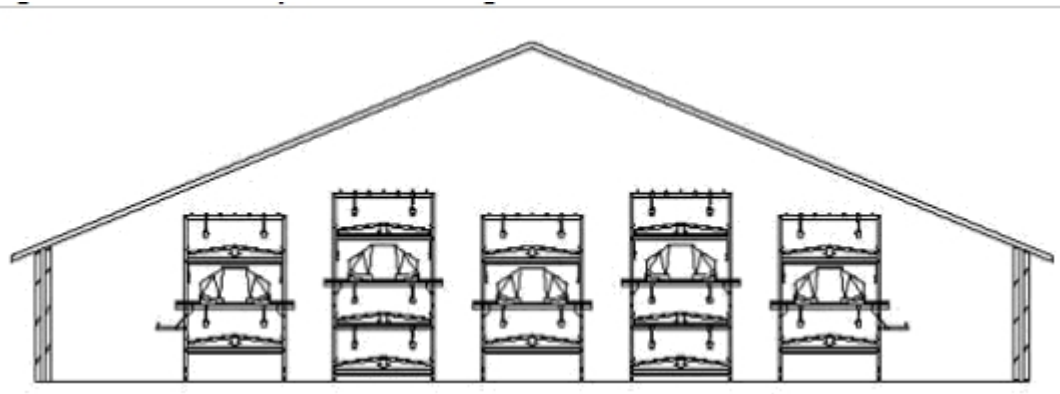


Figure LH4: Example of a multi-tier system (from www.laywel.eu) showing cross-section of an aviary with integrated nestboxes. Designs and configurations of multi-tier systems can vary greatly.

LH1.4c Verandas

Any design of barn (or free-range) housing may also offer veranda or 'winter-garden' extensions that typically are roofed in a similar manner to the main house but have simple wire or plastic mesh sides which allow fresh air and natural light to pass through. Most are accessed via popholes from the main house and have a fully littered floor. Often, extra enrichments in the form of discrete dust-baths, tree branches etc. are provided for the hens and additional feed, water and supplements like grit or oyster shell may be offered. There are few scientific studies on verandas but they are thought to be particularly useful in free-range systems if the birds unexpectedly have to be kept indoors because of disease outbreaks or extreme weather. Verandas also often provide a greater level of natural light than the house. Verandas therefore provide a useful intermediate area between the house and range in free-range houses. The change of light level and temperature is more gradual and the veranda protects the house from the adverse effects of bad weather on litter condition.

LH1.5 Free-range (FR) and organic systems

Free range systems typically provide an indoor ST or MT barn with additional access to an outdoor pasture area often via popholes. Small-scale free-range systems may use mobile rather than fixed barn housing, with a construction similar to a polytunnel on skids with simple natural ventilation and internal layout similar to more permanent single-tier housing. There is variation between countries in the stocking density allowances for indoor and outdoor areas. Stocking rates are generally lower in organic free-range systems. Organic schemes may also specify other requirements e.g. that hens should not be beak-trimmed.

In non-European countries flock sizes can be far larger in both CC and NC systems. Examples of systems used in the USA are provided by Zhao et al. (2015).

LH1.6 Backyard poultry

Backyard flocks are generally small, often less than 10 birds, occasionally reaching up to 50 or so birds. In the UK, poultry flocks of more than 50 birds are required to register with the Animal and Plant Health Agency, for disease control purposes; flocks of fewer than 50 birds are encouraged to register but this is not compulsory. In Australia, a flock of over 50 birds is considered to be a commercial flock. In Victoria, a property with over 100 birds must register for a Property Identification Code to facilitate disease control activities. Backyard flocks may be kept very extensively or may be confined to a small area. Sometimes a cockerel will run with the hens. The birds within backyard flocks will often be fed a variety of food and may be able to forage and perform other natural behaviours. In one study of urban poultry keepers in the UK it was found that poultry knowledge was poor, they rarely employed health prevention measures and they mostly disregarded government feed restrictions for poultry (Karabozhilova et al., 2012).

LH1.7 The Australian laying hen industry

Data from the Australian Bureau of Statistics show that at 30 June 2016 there were over 15.6 million layer hens and almost 4 million pullets in Australia (ABS, 2017a), an increase of 2 million layers and pullets (combined) in each of the preceding two years (ABS, 2015; 2016). The gross value of the eggs produced in the financial year 2015-16 was estimated to be 783 million Australian dollars (ABS, 2017b). Eggs produced from caged birds made up 63% of all

production, with 30% from free range hens, and 7% from barn flocks (ABS, 2017a). There were 130 caged egg farming businesses, 159 barn egg farming businesses and 1,539 free range egg farming businesses (ABS, 2017a).

LH2. FEED AND WATER

The nutrient requirements of laying hens are well-established. Here we review only those contexts where feeding practices are a major contributor to welfare problems.

The nutrient requirements of laying hens have been well-established over many decades. Birds in all housing systems are usually fed *ad libitum* with rations that enable high egg production and satisfy hunger. Clean water is also generally available *ad libitum* in a manner that satisfies thirst. Dietary deficiencies are not specific to any one type of housing system. Food conversion efficiency is similar in conventional and furnished cages (Valkonen et al., 2008; 2009) but tends to be lower in non-cage systems, though some studies have reported no differences (e.g. Singh et al., 2009). The general nutrient requirements of hens are covered in readily available texts (e.g. Nys, 2017).

Here we review briefly the contexts in which feeding practices may contribute to or cause specific welfare problems in laying hens; namely bone strength and injurious pecking. Feed is also a relevant factor in the development of fatty liver disease (LH3.10) and lack of feed (and possibly water) is a significant welfare issue during moulting (LH8.3c).

LH2.1 Relationship between diet, bone strength and risk of fracture

Dietary deficiencies can contribute to bone weakness and increased risk of fracture (LH3.3 and LH3.4), but effective dietary strategies to address these problems require further research.

Calcium is the most important mineral in the structure of bone, and particulate sources of calcium (such as limestone or shell) stay in the gizzard for longer than powdered sources and provide an available source of calcium during the night when egg shell formation takes place. Increasing the amount or particle size of calcium has had a positive effect in some studies (Saunders-Blades et al., 2009) but only affected shear strength in others (e.g. Cufadar et al., 2011), and the magnitude of any effect does not appear sufficient to prevent bone fractures. Strategies to provide additional calcium during the late evening or night when physiological demand is greatest may be a topic for future research (Bain et al., 2016). Supplementation of diets with additional vitamin D (necessary for calcium absorption) had no effect on the prevalence of bone fractures (Kappeli et al., 2011a).

Tarleton et al. (2013) found that feeding hens short chain omega-3 alpha linolenic acid (ALA) markedly (40-60%) and significantly reduced the risk of keel bone fractures and significantly increased bone strength. However, the eggs from these studies, though high in short-chain omega-3, did not contain the high levels of long-chain omega-3 required by consumers. When hen diets were supplemented with high levels of long-chain omega-3 (mostly eicosapentaenoic acid (EPA) in the form of fish oil the benefits were less clear, with those containing the highest EPA content actually having detrimental effects on health and welfare of hens (Toscano et al., 2015). This may have been due to the hens' inability to control prostaglandin levels when exposed to high levels of their EPA precursor. Other authors have reported no beneficial effects of feeding different ratios of omega-3 and omega-6 on femur breaking strength. Feeding a diet enriched with 0.75% conjugated linoleic acid to hens also had adverse effects on their liver function, and increased signs of fatty liver disease (Koronowicz et al., 2016). However, feeding a diet enriched with 10% flaxseed (a source of ALA) to older hens, lowered the incidence of ovarian tumours and reduced overall mortality (Ansenberger et al., 2010; Davis et al., 2016).

Fasting hens towards the end of the laying period, or greatly reducing the quality of the diet to reduce feed costs which will not be recouped by egg production can increase hunger and further reduce bone quality prior to catching and transportation (Newberry et al., 1999).

LH2.2 Relationship between diet and injurious pecking

Dietary deficiencies can contribute to severe feather pecking, which reduces welfare. Increasing the fibre content of the diet and maintaining adequate protein and amino acid levels throughout rearing and laying periods reduces the risk of severe feather pecking.

Injurious Pecking (IP) is described in full in LH3.5.

Severe feather pecking (SFP) can be linked to dietary deficiencies especially relating to inadequate fibre content (Hetland et al., 2003; Van Krimpen et al., 2005; 2009; Steinfeldt et al., 2007; Elwinger et al., 2008; Kriegseis et al., 2012; Qaisrani et al., 2013; Rodenburg et al., 2013). Feeding additional fibre (8% vs 5%) to pullets can actually increase their weight gain (Panaite et al., 2016) and improve gut function (Van Krimpen et al., 2009). The onset of feather damage was delayed by 10 weeks in one study by feeding hens a low-energy, coarsely ground, high fibre diet compared with a normal layer ration (van Krimpen et al., 2008). In another study, feeding a high oil and fibre diet to FR hens was associated with reduced vent injuries (Kalmendal and Wall, 2012). Ingesting small amounts of wood-shavings may be one way that birds can obtain additional fibre in their diets; birds that ingested 4 g/day wood shavings had larger gizzards (Hetland and Svihus, 2007).

Another potential fibre source is the feathers of other birds. These can be found loose on the floor, or can be removed during SFP (Harlander-Matauschek et al., 2006; Harlander-Matauschek and Hausler, 2009). Hens with a high feather pecking tendency will work at a higher rate in formal demand experiments to obtain feathers than hens with a low feather pecking tendency (Harlander-Matauschek et al., 2006). Feather eating is correlated with the number of feathers found on the floor in commercial non-cage systems, but only some researchers (e.g. Hartcher et al., 2016b) have found a positive correlation between feather eating behaviour and plumage quality. This latter relationship was not observed by Riber and Hinrichsen (2016b). Although the experimental inclusion of 10% shredded feathers to the diet reduced SFP bouts and improved feather condition (Kriegseis et al., 2012), the causal relationship between feather eating and feather pecking is not yet clear (Hartcher et al., 2016b).

Fermented forage sources can provide additional dietary fibre. In a Canadian trial, hens housed in FCs and provided with an *ad libitum* laying hen ration consumed approximately 50 g/bird/day of barley silage, voluntarily reducing their consumption of the accompanying concentrate ration by approximately 11%. This had no adverse effects on production, bodyweight or markers of physiological stress but it significantly reduced aggression and SFP (Johannson et al., 2016). In free-range systems hens have an additional opportunity to ingest forage material. This is both a potential benefit (in increasing fibre levels) and a drawback if the overall diet becomes unbalanced (see LH2.3).

Feather pecking has also been related to inadequate amino acid and protein levels. Feeding a purely plant-based diet during rearing resulted in more vigorous feather pecking in pullets aged 13-16 weeks than a diet that included fishmeal, but this was a short-lived effect (McKeegan et al., 2001). Van Krimpen et al. (2011) housed hens for 20 weeks and fed them on either an entirely plant-based diet or on one of 4 diets containing meat or bone meal. The development of feather pecking was delayed in hens fed the meat and bone meal compared with hens fed a bone-meal diet only. In some cases, birds that initiate severe, cannibalistic tissue pecking appear to chase and hunt their companions as if they were prey. Birds selected for high feather pecking appear to have altered feeding motivation, and show an increased number of bouts and a faster rate of eating mealworms than low feather pecking lines (De Haas et al., 2010).

LH2.3 Free-range and organic diets

Free-range systems provide a potential opportunity for hens to obtain fresh forage, but at high stocking densities pasture quality can be rapidly depleted. Diets that prohibit animal components may be short of some amino acids.

Free-range hens have the potential opportunity to obtain a proportion of their nutrient requirements from plants growing on the range (Horsted and Hermansen, 2007). Hens with good and varied plant cover on the range are observed pecking directly at plants (Breitsameter et al., 2014) and are able to maintain condition and rates of lay with only some supplementary wheat feeding (Horsted and Hermansen, 2007). However, it is difficult to maintain pasture quality (Maurer et al., 2013). Hens rapidly deplete the range, and as percentage sward cover falls, hens are observed to do more ground pecking and less scratching, plant pecking and sward-directed pecking (Breitsameter et al., 2014).

Organic diets (and other diets that prohibit components of animal origin) may be short of essential amino acids. An organic diet will not necessarily reduce bird welfare, but pullets grow better if organic diets are supplemented with certain amino acids, such as methionine (Acamovic et al., 2008). Organic diets are required to contain a proportion of forage, which is likely to have beneficial effects on hen welfare, and also can improve egg quality (Hammershoj and Steenfeldt, 2012). Diets including insect protein are showing much promise, with no adverse effects on welfare detected in medium-growing free-range female broiler hybrids (Biasato et al., 2016), although we can find no published work yet on laying strains.

LH3. RISK MANAGEMENT

LH3.1 Mortality

Flock mortality rate provides critical information about bird welfare. There is more information on flock mortality rate than any other welfare indicator and large compilations of data show that mortality rates in furnished cages are lower and more consistent than in other housing systems. Mortality rates in non-cage and free-range systems are highly variable.

Generally animal welfare is measured at the level of the individual, but much can be inferred from an assessment of overall flock mortality rates. Indeed flock mortality rate is considered by experts to be one of the most important animal welfare indicators for laying hens (Rodenburg et al., 2008b). An increase in mortality over expected levels (published breed standards) should be a cause for some action. Unlike the focused culling seen in the broiler and broiler breeder sectors (BB3.1a), laying hens are only rarely culled if, for example, they are found to be moribund or severely injured. Many injuries (e.g. to the vent or keel bone fractures) are not easy to identify and it is also more difficult to identify and capture ailing birds in large tiered cage or aviary systems. Where high levels of mortality are recorded there should be an attempt to determine the causes in order to manage and rectify the situation. Dead birds are those which could not 'cope' with the challenges of their environment. If overall flock mortality is increased, the welfare of the birds that remain in the flock is also likely to be compromised or threatened.

In making overall assessments about hen welfare it is important to obtain widespread data on mortality in different types of housing systems and assess how these relate to the expected breed standards. Data on mortality from experimental studies and commercial farms often far exceeds the published breed standards, demonstrating the range of environmental challenges facing laying hens. Mortality rates are most often compared at 40 weeks of age and at “end of lay” when birds are sent for slaughter, typically at approximately 72 weeks of age.

One of the first compilations of mortality data across different studies was conducted within the LayWel project (LayWel, 2006) which obtained data from 1.2 million laying hens, which had been studied in experimental trials (430 treatments) in 7 European countries. This study was done at time when furnished cages were in initial development (Laywel, 2006), so few data were available on larger group colony cages.

The LayWel (2006) project reported significant differences in end of lay mortality according to breed and beak-trimming status (Tables LH1a and LH1b), with seemingly smaller differences attributed to housing system, although there was high confounding amongst some variables (e.g. many early trials on FCs used intact-beak birds; brown hybrids were more likely to be placed in non-cage systems).

Table LH1a: Mean levels of mortality at end of lay

	White beak-trimmed	Brown beak-trimmed	White intact-beak	Brown intact-beak
Mortality	3.0%	9.3%	10.5%	19.0%

Table LH1b: Mean levels of mortality at end of lay

	CC	Small group FC	Non-cage
Mortality	8.3%	7.1%	11.8%

Subsequently, Freire and Cowling (2013) conducted a simple form of quantitative analysis on 35 studies that had been published between 1974 and 2010. Of these, 19 had reported comparative mortality data for conventional cages vs other systems. 11/18 studies reported higher mortality in non-cage than cage systems, with no difference in mortality outcomes for studies that compared CC and FC systems. Rakonjac et al. (2014) also concluded on the basis of a non-quantitative review of a selection of European studies published between 1995 and 2012 that non-cage systems tend to have higher mortality.

A more recent and very thorough quantitative analysis of levels of mortality in 3,851 commercial flocks, recorded as part of ten different scientific studies across Europe (Weeks et al., 2016), is shown in Figure LH5. Of those 3,851 flocks, 26 had also been included in the analysis conducted by Freire and Cowling (2013) but this was the only overlap. The data from Weeks et al. (2016) clearly illustrate the low mortalities now being achieved in commercial FC systems. Figure LH5 also demonstrates that in a substantial minority of loose-housed flocks the levels of mortality can become extremely high.

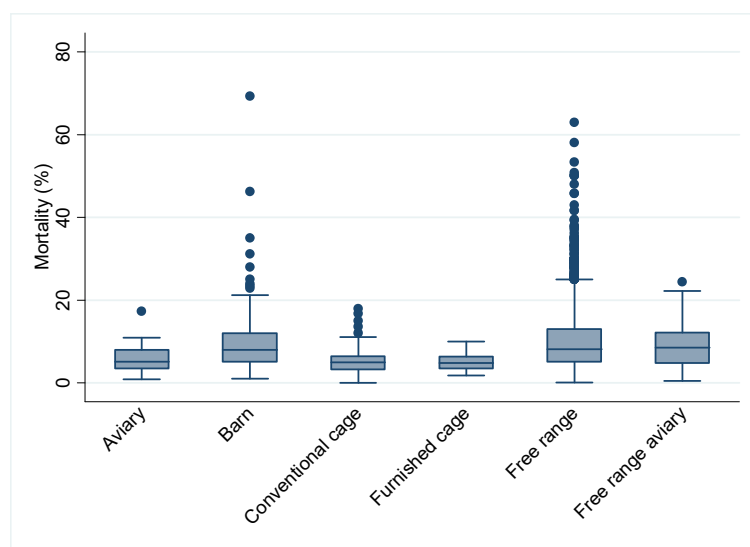


Figure LH5: Comparative levels of mortality in each housing system recorded at 60-80 weeks of age (medians and inter-quartile range (IQR))

For the purposes of this review, we extracted additional mortality data from recent studies that had *not* been included in either the reviews of Freire and Cowling (2013) or Weeks et al. (2016) (Figure LH6; Table LH2). The unweighted means (taking no account of number of studies or flocks contributing to each paper) present the same overall pattern, with lowest and most consistent mortality from FC systems, and highly variable outcomes from non-cage systems.

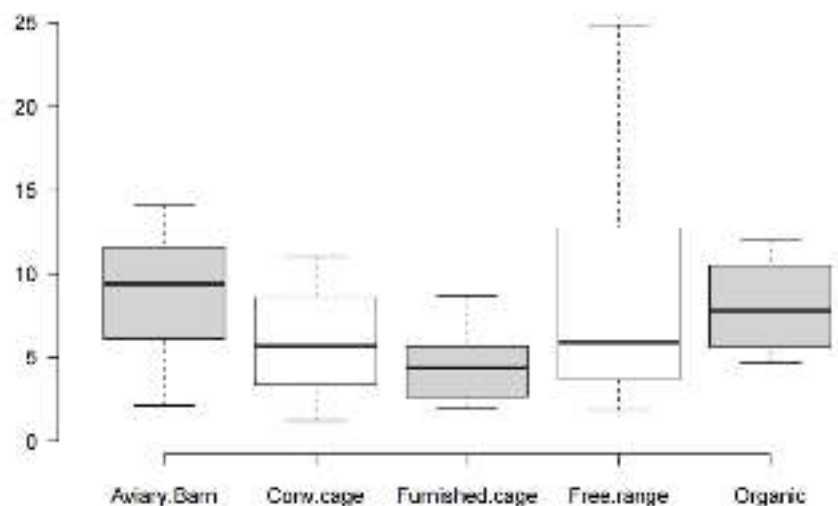


Figure LH6: Comparative levels of mortality (%) in each housing system (medians and IQR) derived from (unweighted) studies listed in Table LH2

Table LH2: Average mortality (%) figures reported in studies not included in previous reviews

Study	CC	FC	Non-cage	Free-range	Organic
Agra CEAS, 2004	6.0	4.47			
Anderson & Havenstein, 2007	8.7				
Aral et al., 2017	3.93	1.98			
Aral et al., 2017	2.86	2.78			
Dikmen et al., 2016	1.25	6.25		1.88	
Ferrante et al., 2009			4.24	2.43	
Gerzilov et al., 2012	5.4	7.9	9.4		
Golden et al., 2012	8.9			24.88	
Guinebretiere et al., 2013		2.5			
Huneau-Salaun et al., 2011b		3.2			
Karcher et al., 2015	4.7	5.1	11.5		
Landman and van Eck, 2015		4.3	14.1	18.9	
Leenstra et al., 2012 (Swiss)				5.9	6.6
Leenstra et al., 2012 (French)				4.9	4.7
Leenstra et al., 2012 (NL flocks)				6.6	12.0
Mielenz et al., 2005	6.3				
Petrik et al., 2015	1.29		2.13		
Rodenburg et al., 2008a		2.3	8.0		

Study	CC	FC	Non-cage	Free-range	Organic
Sterling et al., 2003	8.52				
Van der Meulen et al., 2007					9
Weber et al., 2003	11	8.7	11.7		
Weitzenburger et al., 2005b		av 4.5			
Unweighted mean	5.7	4.5	8.7	9.4	8.1

LH3.2 Causes of mortality

Hens are proportionately more likely to die from infectious or parasitic diseases in non-cage systems with access to litter. In conventional cage systems where hens receive little exercise, osteoporosis and fatty liver disease are proportionately more common causes of mortality. Injurious pecking is a major cause of death in all systems. Predation is a cause of death in free-range systems.

Although overall mortality in cage systems is generally low, one of the principal causes is osteoporosis, which accounts for the deaths of 20-35% of caged white hybrids (Enneking et al., 2012). Injurious pecking is another cause of death in caged birds, with over 65% of FC mortality ascribed to this cause (Weitzenburger et al., 2005b). Not all deaths are submitted for post-mortem examination and so assessments of cause of death from this source reflect non-random samples. However, they can still be informative. Swedish post-mortem results revealed proportionately more deaths associated with bacterial diseases such as erysipelas, viral diseases such as lymphoid leukosis and Marek's disease, parasitic infections such as coccidiosis, and cannibalism in non-cage and free-range flocks compared with birds in cages (Fossum et al., 2009) (Table LH3). Sossidou (2011) also found increased mortality in free-range systems due to disease and parasitic infections. Environmental microbiology assessments confirm a relatively high presence of aerobic and coliform bacteria in litter areas in non-cage systems and on the scratch pad mats provided in FCs (Jones et al., 2015).

Fossum et al. (2009) also noted an association between vent-injuries or cannibalism and *Escherichia coli* infections such as colibacillosis. High levels of infectious disease have also been reported in other studies of non-cage flocks (Weber et al., 2003; Van der Meulen et al., 2007).

Table LH3: Causes of mortality in hens submitted for routine necropsy in Sweden (2001-2004) (Fossum et al., 2009)

Housing system	Bacterial diseases %	Viral diseases %	Parasitic %	Cannibalism %
Cages (conventional and furnished not distinguished)	65	30	10	5
Non-cage	73	11.6	18	19
Free-range	74	4.4	22	26

A recent survey of post-mortem results from 308 birds submitted from 15 non-cage houses on 3 farms in the USA (Kajlich et al., 2016) found the following lesions (Table LH4):

Table LH4

Lesion	Hens/308
Cloacal cannibalism	152
Keel bone deformation	150
Beak length abnormalities	124
Severe loss of feather cover	123
Cloacal prolapse	94
Foot pad dermatitis	75
Septicaemia	71

Lesion	Hens/308
Comb paleness	67
Toe damage	65
Enteric disease	35
Respiratory disease	34
Roundworms	33
Cage layer fatigue*	28
Enlarged crop	24
Feather pecking	23
Neoplasm	7
Northern fowl mites	5
Eye abnormalities	5
Skin lesions	4
Bumblefoot	2
Tapeworms	1
Lice	1

**The term cage layer fatigue is often used without a clear definition to refer to a variety of forms of bone disorder and osteoporosis affecting (primarily) caged birds that have little opportunity to exercise, often resulting in total lameness, paralysis and collapse. The term can also be used to describe a form of developmental bone disorder where characteristic beading (knobs) are observed at the junction between ribs and vertebrae. This is the sense in which it is used by Kajlich et al. (2016).*

Smothering occurs when birds aggregate and pile on top of each other. A survey of UK free-range flocks found the average number of birds killed during a smothering episode was 25, and that overall cumulative mortality due to smothering was 1.6% (Barrett et al., 2014). Smothering can also be a significant cause of mortality in pullets during the rearing period, where overall mortality is usually low (Sparks et al., 2008). Smothering accounted for 16% of all mortality in intact-beak flocks, where overall mortality was high (Defra, 2015). Some smothering is linked to episodes of panic (Richards et al., 2012a), which may be mitigated by improved rearing practices that accustom young birds to a wider range of stimuli. However, panic is not the only cause of smothering. Hens can smother inside nest-boxes, or can engage in a form of “creeping” smothering which can occur in any part of the house or even on the outdoor range (Bright and Johnson, 2011). Some hens have been observed crowding into the same small areas, possibly associated with synchronous dust-bathing behaviour, and then piling on top of each other (Campbell et al., 2016c), or circling slowly and pushing underneath each other as if seeking shelter or cover. These behaviours may not always lead to smothering (Campbell et al., 2016c) but they can do so. This type of smothering generally involves fewer birds than when a whole flock panics, but nonetheless can lead to high overall mortality if episodes are frequent. Rearing birds with access to perches may reduce smothering (Lay et al., 2011) and nest box design has also recently been found to affect smothering risk, with nest boxes manufactured by some companies (unspecified) reducing the risk compared with those manufactured by other companies (Rayner et al., 2016).

Trauma (Fossum et al., 2009) and other accidents (e.g. access to some types of string causing impaction and tongue necrosis (Schlegel and Brash, 2015) can also lead to high mortality.

Predation in free-range flocks is an additional cause of losses. In intact-beak free-range flocks, predation accounted for between 5 and 6% of overall mortality, depending on bird age at assessment (Defra, 2015).

Despite these average figures, well-managed and designed free-range systems can produce low-mortality outcomes. Ferrante et al. (2009) reported much lower mortality in free-range than in barn systems (2.43% vs 4.24%). There is some evidence (see LH3.13) that well-managed systems can produce birds with high immune function (e.g. Shimmura et al., 2010b), able to deal with the additional disease challenges in their environment.

The high ovulation rate of laying hens makes them increasingly susceptible to ovarian cancer with age. Ovarian cancer can often be detected in hens of 2 years of age, and by 3.5 years, over 30% of hens will have this condition (Johnson and Giles, 2013). This makes the laying hen the best current animal model for human ovarian cancer studies (Johnson and

Giles, 2013; Hawkrigde, 2014). For commercial flocks depopulated at 70 to 80 weeks this condition has little welfare impact. However, it is a relevant welfare concern for flocks that are moulted and expected to produce eggs in their second year. It remains to be seen whether new strains that produce at commercial rates for longer (with predicted depopulation age approaching 100 weeks) are also susceptible to ovarian cancer.

LH3.3 Bone fractures and damage

Laying hens are highly susceptible to fractures of the keel bone which can occur during the laying period (once healed these are termed 'old' fractures) or at depopulation (see LH3.4). Fractures sustained during the laying period appear to be painful, even after the healing has taken place, and they restrict bird movement to some degree. As such, fractures are a welfare concern. Fractures sustained during the laying period are observed in all housing systems but are most common in systems which present a high risk of collision.

The prevalence of all bone fractures was assessed using radiography, for hens of diverse strains housed in conventional cages. On average, 15.7% of birds had sustained a fracture by 65 weeks, with high variation between strains in fracture incidence (which was greatest in Rhode Island Red lines) (Clark et al., 2008). Indentations of the keel bone were also noted in between 36 and 88% of hens from these same lines (Clark et al., 2008). This fits well with the considerable body of evidence emerging to indicate that many highly productive commercial laying hens in all housing systems have some degree of abnormality of their keel bone. The extent of damage ranges from deviations (bends and twists) to multiple severe fractures. The prevalence and severity tends to increase with the complexity of the housed environment. Keel bone deviations appear to arise from contact of the keel with a perch during rest (Vits et al., 2005).

Keel bone fractures occur very rarely or not at all (Kappeli et al., 2011a; Richards et al., 2012b) during the rearing period. The incidence of fractures increases with age in both cage and non-cage facilities (Richards et al., 2012b; Petrik et al., 2015) (Table LH5).

Table LH5: Prevalence of keel fractures at different hen ages

Age (weeks)	Richards et al., 2012b	Petrik et al., 2015
20-25	5.5	8.2
30-35	25.5	36.0
45-50	49	46.3
55	63	
65	66	48.2
>68	78.5	

Several approaches have shown that keel fractures affect bird mobility (though this is not always apparent to the naked eye). Hens with fractures are less likely to use pop-holes to access an outdoor range area (Richards et al., 2012b). Nasr et al. (2012a; 2012b) found that hens with keel fractures were reluctant to move down from a perch but their latency to leave the perch was reduced when they were given analgesic (pain killer) drugs. In addition hens with keel fractures showed a preference for a place associated with analgesia (Nasr et al., 2013) whilst uninjured birds did not. These strands of evidence strongly suggest that hens experience pain associated with keel fractures.

When comparing cage systems, the lowest prevalence of keel damage is reported in conventional cages (17.7% (Sherwin et al., 2010); 24.8% (Petrik et al., 2015) with intermediate levels of keel damage reported in furnished cages (62%, Rodenburg et al., 2008a; 31.7%, Sherwin et al., 2010; 36%, Wilkins et al., 2011). In small experimental floor pens, keel fracture prevalences of 35% and 44% have been reported by 65 weeks of age (Kappeli et al., 2011a). However, birds in FCs have greater bone-strength (LH3.4) and a far lower prevalence of fracture at depopulation (Sherwin et al., 2010). However, it must be noted that the prevalence of *new* fractures, sustained during depopulation is higher for hens housed in conventional cages than any other system (Sherwin et al., 2010). During depopulation, birds are caught manually by their legs and, in cage systems, pulled through cage fronts, before being carried by the legs in groups and placed rapidly into transport crates or modules situated at the one end of the house. The weaker bone strength of hens from CC means that they are highly susceptible to any impact during this process.

Far greater levels of keel damage and fractures are observed in non-cage systems and there is a consensus that collisions are the cause of most severe fractures of the keel (e.g. Fleming et al., 2004, who ruled out developmental factors). In single-tier non-cage systems fracture rates of 50–78% (Wilkins et al., 2004), 60% (Nicol et al., 2006), 82% (Rodenburg et al., 2008a), 59–67% (Wilkins et al., 2011) and 48.3% (Petrik et al., 2015) have been recorded. The highest level of fractures occur in systems with the greatest combined available heights suitable for perching (97%, Rodenburg et al., 2008a; 86%, Wilkins et al., 2011; 82.5%, Heerkens et al., 2016a). Such systems also result in fractures with much higher severity scores (Wilkins et al., 2011), although the adverse effect of aerial perches itself depends on other farm level factors and is apparent on some farms but not others (Donaldson et al., 2012). A study of two consecutive flocks housed in an aviary system noted that 9.1% (flock 1) and 21% (flock 2) of all flights failed, with birds colliding with other

hens, slipping on the ground or colliding with aviary structures (Campbell et al., 2016a). Landings on perches failed more often than landings on litter. Designs of non-cage systems are changing accordingly, although there is still a need for more information. A recent survey of Danish flocks aged 62 weeks (Riber and Hinrichsen, 2016a), confirmed that greater bone damage occurred in multi-tier than single-tier systems (11.6 vs 4.9%) but the overall levels of damage were far lower than have been reported earlier or elsewhere. A relatively low prevalence of 18.7% keel bone fractures in Danish organic flocks (approx. 3,000 birds/flock) has also been recently reported (Hinrichsen et al., 2016), although levels were again higher in flocks with MT indoor structures. Changing genotypes (or simply differences between white and brown hybrids), improved design features within non-cage systems or differences in access to limestone (which could potentially influence bone density) may all be explanatory factors for these lower levels of damage.

The height from which birds need to fly or jump down appears to be strongly associated with risk of damage and inaccurate landings. This may partly be due to an increased force of landing with increased height. Banerjee et al. (2014) found an average landing force for a hen jumping from a height of 41 cm to be 81 N, which increased to 107 N for hens jumping from heights of 61 cm.

The risk of keel fractures increases when hens have to jump a distance of more than 80 cm vertically, horizontally or diagonally to reach or leave a perch, or jump an angle between 45 and 90° (measured at the horizontal plane) (EFSA, 2015). MT systems are associated with an increased risk of bird collisions and falls and subsequent keel bone injuries (Kappeli et al., 2011b). Good MT systems also provide a way for the birds to move down the tiers (and down to the litter) without large jumps. Systems that incorporate soft-perches i.e. metal or wooden perches covered with approximately 3 mm thickness of soft polyurethane (Pickel et al., 2010; Stratmann et al., 2015b) and/or ramps or 'stepped' slats are therefore preferable, and this is an active research area (Stratmann et al., 2015a; Heerkens et al., 2016b; Pettersson et al., 2017).

LH3.4 Bone strength and disuse osteoporosis

Stronger and more flexible bones are less likely to sustain fractures. The provision of exercise, particularly during adult life, increases bone strength.

Bones need to experience weight-bearing in order to maintain their structural strength. In conventional cages, the restriction of movement is particularly severe, leading to considerably reduced bone strength that in turn makes the birds susceptible to sustaining fractures of the leg and wings, during depopulation in particular (Sherwin et al., 2010). Indeed these authors found that fractures at depopulation were nearly five times more common in hens from conventional cages than from other systems. The bone weakness of confined hens has been termed disuse osteoporosis and cage layer fatigue. Neither term fully describes the syndrome. Compared with conventional cages, the strength of tibia (leg) and humerus (wing) bones (in particular) is improved in furnished or colony cages where birds exercise by moving on and off perches (Wilson et al., 1993; Guesdon et al., 2004; Leyendecker et al., 2005; Vits et al., 2005; Jendral et al., 2008; Barnett et al., 2009; Tactacan et al., 2009; Hester et al., 2013; Dikmen et al., 2016; Regmi et al., 2016b; Meng et al., 2017), although one study found no significant difference (Onbaşlılar et al., 2016) and another found a difference only in tibia ash content (Valkonen et al., 2010). Improved calcium and phosphorus utilisation in birds housed in FCs is also observed (Neijat et al., 2011). As the complexity of furnished cages increases (e.g. German small group housing system) bone strength again increases (Scholz et al., 2008b; 2009). Bone strength is generally further improved in non-cage systems (Leyendecker et al., 2005; Lichovnikova and Zeman, 2008; Scholz et al., 2008b; Sherwin et al., 2010; Freire and Cowling, 2013; Dikmen et al., 2016; Regmi et al., 2016a; 2016b; Tumova et al., 2016). Although the rearing system has some effect on adult bone strength, with early access to perches improving the bone mineral content of tibia, sternum and humerus bones (Enneking et al., 2012), the opportunity to move and exercise in adult life has perhaps the major effect on adult bone quality (Regmi et al., 2016b).

Most studies have found the greatest bone strength in both wing and leg bones in free range systems, which offer the greatest freedom of movement in all directions and access to sunlight and dietary supplementation, as indicated in Table LH6. This table, which is reproduced from Wilkins et al. (2011), compares bone strength in different housing systems, highlighting the influence of design details such as the type of and placement of perches. The keel strength was measured at two different points (A & B).

Table LH6: Peak bone breaking strength (kg)

System	Tibia	Humerus	Keel A	Keel B
FR	22.9	18.7	31.4 high	13.9 high
FRAA	20.8 low	19.1	25.1 low	10.9
FRAS	23.6	21.9 high	27.6	11.5
OM	28.8 high	21.3 high	33.2 high	13.3 high
OMAF	24.3	23.4 high	29.4	12.7
OS	24.9 high	19.5	31.0	12.2
Barn	21.9	18.6	30.6	13.7 high
FC	19.1 low	14.3 low	23.6 low	9.7 low

The terms low and high indicate the most significant differences.

Barn = House with a single tier of slats raised above a litter area, FC = Furnished cage containing multiple raised perches, FR = Free-range, FRAA = A-frame perches with additional horizontal bars above the apex of the frame, FRAS = Indoor house equipped with aerial suspended perches, OM = Organic mobile, OMAF = Organic mobile equipped with two rows of three fixed aerial perches, OS = House with a single tier of slats raised above a litter area.

Bone strength may be altered by genetic selection but there appear to be trade-offs between improving bone strength and reducing egg quality (Stratmann et al., 2016). In this study, birds selected for higher bone strength also had significantly higher mortality.

Delaying the onset of lay by approximately 2 weeks can increase bone density (Silversides et al., 2006). In a study that manipulated lighting period, hence delaying the closure of bone growth plates, young hens were produced with longer bones, but this treatment did not improve bone mineralisation or density in older adult birds at 66 weeks (Hester et al., 2011). Bone strength can also be improved by the injection of bone anabolic compounds into fertile eggs (Saki and Mahmoudi, 2015) but the commercial feasibility of such a strategy has not been evaluated.

The practice of forced moulting has a substantial negative impact on bone mineral density and content (LH8.3c).

LH3.5 Inter-bird pecking

LH3.5a Gentle feather pecking

Gentle feather pecking (GFP) of feather tips occurs commonly during both the rearing and laying periods (Lambton et al., 2010; Gilani et al., 2013; Nicol et al., 2013). GFP is sometimes directed towards unfamiliar chicks as a form of social exploration (Riedstra and Groothuis, 2002) or it can take a more stereotyped form. GFP results in minor plumage damage so it is a welfare concern mostly because of its possible relationship with more serious types of injurious pecking. A handful of studies have suggested that GFP may precede or develop into SFP in older birds, possibly because feathers with minor damage and fraying become more attractive targets for more serious pecks in later life. However, the majority of studies, especially those on commercial flocks, have shown no clear causal or temporal link between early GFP and adult SFP (Rodenburg et al., 2013; Hartcher et al., 2015a). However, further work is needed to clarify relationships between different types of inter-bird pecking.

LH3.5b Injurious (severe) feather pecking

Injurious severe feather pecking is a highly prevalent problem that results when normal exploratory or foraging pecking is directed towards other birds. There is a strong genetic component to the behaviour but breeds have not yet been developed with both a low tendency to peck and high productivity. The importance of preventing the development of feather pecking during the rearing period is recognised. The use of a comprehensive package of management strategies during both rearing and laying periods has been shown to significantly reduce (but not eliminate) injurious pecking on commercial farms.

Severe feather pecking (SFP) is painful for the recipient, results in substantial plumage loss (Gunnarsson et al., 1999; Bestman and Wagenaar, 2003; Drake et al., 2010; Lambton et al., 2010), skin damage, increased susceptibility to infection (Green et al., 2000), loss of production, increased demand for food, and higher mortality (Bright et al., 2011; Nicol et al., 2013; Rodenburg et al., 2013). The exposure of bare patches of skin can trigger subsequent tissue pecking which can result in rapid mortality and cannibalism of living birds or of carcasses. There is no clear relationship between gentle feather pecking and severe feather pecking (Newberry et al., 2007; Lambton et al., 2010). However, there is a relationship

between feather pecking and cannibalism (Cloutier et al., 2000; McAdie and Keeling, 2000; Pötsch et al., 2001), and specifically between SFP and vent pecking (LH3.5c) (Lambton et al., 2015). Severe injurious pecking directed to the vent area or near the preen gland can also arise spontaneously in the absence of prior feather pecking, so the risk factors for each type of injurious pecking should be considered both separately and together.

All types of injurious pecking appear to be a form of normal pecking redirected inappropriately to another bird. If other pecking substrates are less attractive than the feathers of a neighbour then pecks, normally directed towards litter particles, may be directed at feathers instead. Birds with a strong foraging tendency when young may be those most likely to show SFP when older (Newberry et al., 2007) and there are other strong breed relationships between foraging tendency and tendency to feather peck (Klein et al., 2000). Absent or poor-quality litter is thus a major risk factor for injurious pecking (IP) (Huber-Eicher and Wechsler, 1998; Nicol et al., 2001), with an inverse relationship seen between time spent foraging on harmless substrates and time spent feather pecking (Klein et al., 2000). Reduced foraging opportunities appear to interact with high levels of bird fearfulness or stress to increase the overall risk of feather pecking. This interactive effect was demonstrated in a study by El-Iethy et al. (2001) where birds housed on litter performed, as expected, less feather pecking than birds housed on slats. But if the litter-housed birds were directly fed corticosterone, increasing their plasma concentrations to levels seen under physiological stress, feather pecking rates increased significantly. The important link with foraging has implications for considering feeding practices to reduce the risk of injurious pecking. In epidemiological studies of hens housed on commercial farms, feeding mash rather than pellets has been strongly associated with reducing the risk of SFP (Green et al., 2000; Lambton et al., 2010) and of vent pecking (Lambton et al., 2015). Experimental trials have not always replicated this effect (Wahlstrom et al., 2001) but generally, hens spend far more time foraging in diets presented in mash form, this in itself reducing the opportunity for feather pecking. Protein source and other dietary factors also play a significant role in the development of SFP (see LH2.1). Changes in diet, particularly if the new diet is of lower nutritional quality or contains less preferred ingredients than the previous diet, are a strong risk factor for the development of injurious pecking (Green et al., 2000; Dixon and Nicol, 2008). Gilani et al. (2013) reported a 64-fold reduction in risk of IP if the number of diet changes during the rearing period was reduced by one.

There is a genetic component to injurious pecking evidenced by differential breed tendencies (Kjaer and Sorensen, 2002; Hocking et al., 2004), by divergent experimental selection programmes (Kjaer, 2009) and by more formal genetic analysis (Ellen et al., 2008; Alemu et al., 2016). In experimental studies it has proved easier to produce birds with very high or even extreme levels of feather pecking (HFP lines), than to reduce feather pecking to consistently low levels (LFP lines) (Labouriau et al., 2009). Further work is needed to establish the genetic x environmental interactions that affect indirect or social traits, and the extent to which results obtained from birds kept in relatively small experimental groups can be applied to situations where birds are kept commercially in groups of many thousands is not yet clear (Ellen et al., 2014; Alemu et al., 2016). In addition, application to the commercial situation has been limited by the existence of positive correlations between feather pecking and useful production traits, such as early onset of lay and the ability to use calcium to produce good quality egg shells (Väisänen et al., 2005; Su et al., 2006; Buitenhuis and Kjaer, 2008). In addition, behavioural feather pecking traits are controlled by many genes with small effects, with Lutz et al. (2017) concluding that no one single nucleotide polymorphism (SNP) had effects sufficient to justify its use in marker-assisted selection. In addition, obtaining sufficient phenotypic data on long-term parameters such as later life plumage score is challenging (Sun et al., 2014). All of these factors mean that it may prove more difficult than hoped for breeding companies to develop strains with phenotypes that are both highly productive and unlikely to exhibit feather pecking. An alternative approach to selecting directly for the feather pecking trait is to select birds on the basis of their ability to survive when housed in groups (Cheng et al., 2001a). Birds selected for increased survivability in this way also show reduced cannibalism, fearfulness, markers of stress (such as heterophil:lymphocyte (H:L) ratio) and measures of improved immune function such as higher ratios of CD4+ and CD8+ T cells. In addition, when mixed with unfamiliar individuals, birds selected for high group survival have lower blood corticosterone levels (Cheng et al., 2001a; 2002). The high survival lines also showed lower circulating levels of dopamine and serotonin (Cheng et al., 2001b; 2002). The question is to what extent the (few) breeding companies that produce commercial strain birds will utilise this basic research to prioritise a reduction in feather pecking as a trait for selection in their breeding models, given that they produce birds for a global market.

Feather pecking, or feather damage ascribed to feather pecking, has been reported in 40% of rearing flocks by 5 weeks, and 77% of flocks by week 14 (Huber-Eicher and Sebo, 2001a), in 54% of rearing flocks by week 16 (Bestman et al., 2009), and in 60% of rearing flocks between 5 and 15 weeks (de Haas et al., 2014a), whilst severe feather pecking (SFP) has been observed in 27% of rearing flocks by 16 weeks (Gilani et al., 2013). Feather pecking in young pullets can be socially transmitted (Zeltner et al., 2000) either directly, or because slightly damaged plumage becomes a yet more attractive pecking stimulus (McAdie and Keeling, 2000). Feather pecking may not result in injuries at this age, but is a predisposing factor and strong risk factor for the later development of severe pecking in adult birds (Nicol et al., 2001; Dixon and Nicol, 2008; Bestman et al., 2009; Drake et al., 2010; Gilani et al., 2013; Nicol et al., 2013; de Haas et al., 2014a; Tahamtani et al., 2016). Bestman et al. (2009), for example, found that 90% of rearing flocks with feather damage due to pecking continued to experience pecking in the laying period.

Studies on birds during the rearing period are more recent than work on adult birds and it is not yet known how best to prevent the development of feather pecking in young pullets. Ideally good quality litter should be present during rear, with

many studies showing that early feather pecking in chicks or young pullets is prevented or reduced by the provision of good quality litter substrates (Huber-Eicher and Sebö, 2001b; Chow and Hogan, 2005; Bestman et al., 2009). However, litter provision during the very early rearing period (1 to 21 days) does not always provide later adult protection. De Jong et al. (2013a; 2013b) found that although young chicks used good quality substrates when they were available, this had only marginal effects on their adult behaviour, with slight reductions in gentle feather pecking but no effect on feather quality in older birds. Thus, although providing good quality pecking substrates during very early rear can reduce the risk of adult feather pecking, it does not prevent it. The provision of suitable substrates during the later rearing and laying period appears to have a greater effect (Nicol et al., 2001; de Jong et al., 2013a; 2013b). Adult birds are not constrained by their early experience in terms of foraging substrate preferences and can readily accept novel, but suitable, materials (Nicol et al., 2001).

In addition to providing a good, friable litter substrate, other ways of encouraging harmless pecking have been explored in both young and adult birds. These include the provision of hay bales (Daigle et al., 2014), pecking strings (Jones et al., 2000; McAdie et al., 2005), pecking objects (Moroki and Tanaka, 2016a) and pecking blocks (Holcman et al., 2008). Dixon and Duncan (2010) found no effect of providing a peat moss substrate compared with wire on the pecking behaviour of young chicks but the provision of foraging materials for older pullets significantly reduced feather pecking behaviour compared to non-enriched treatments. Foraging materials were significantly more effective in reducing feather pecking than other enrichments such as dust-bathing substrates, or novel objects (Dixon et al., 2010). Another study found a positive effect of environmental enrichment (pecking strings, whole oats and increased litter depth provided from 12 days of age) during the rearing period, but the effect did not persist or was not sufficiently strong enough to improve plumage condition when the birds were 43 weeks of age (Hartcher et al., 2015a). Allowing free-range hens early access to the range (18 weeks rather than 22 weeks) significantly improved plumage quality in later life (Petek et al., 2015).

The risk of more serious types of injurious pecking is greatly increased as birds come into lay (Newberry et al., 2007; Nicol et al., 2013). SFP has been reported in 68.5% of free-range flocks at 25 weeks of age, and 85.6% of flocks at 40 weeks. Levels of feather damage tend to worsen over the laying period (LaBrash and Scheideler, 2005), including in free-range systems in Australia (Moyle et al., 2016).

Within cage systems, plumage condition is improved by increased space allowances (Elson, 2004, cited by Widowski et al., 2016) and, in some studies (e.g. Meng et al., 2015; Onbaşilar et al., 2015) plumage condition is better in furnished cages than conventional cages.

It is hard to compare the prevalence of severe pecking in cage and non-cage systems because feather loss (the most common proxy measure of severe pecking) can also occur due to abrasion in cage systems. This may explain why in a meta-analysis, Freire and Cowling (2013) found no overall difference between birds housed in conventional cages and birds in other systems. Blatchford et al. (2016) also found better plumage cover in birds from aviaries than birds from furnished or conventional cages, probably because of more abrasion in the latter.

In a systematic comparison of different housing systems comparing 26 flocks, Sherwin et al. (2010) found a lower proportion of birds in free-range systems had substantial feather damage, but that these birds were more likely to show (relatively mild) pecking wounds to the vent (see Table LH7).

Table LH7: A comparison between housing systems of feather damage and vent wounds

Housing system	% hens with substantial feather damage	% hens with signs of vent wounds
Conventional cage	24.7	6.2
Furnished cage	24.9	1.6
Non-cage (ST, MT)	26.9	10.0
Free-range	15.5	22.5

In a study of 47 non-cage flocks, Heerkens et al. (2015) found better plumage condition in flocks with access to the range than in indoor aviary flocks. Shimmura et al. (2008c) directly compared hens housed in ST aviaries and FR systems. Although the proportion of time devoted to pecking behaviours was similar, the FR hens directed their pecking towards foraging substrates on the range, whilst the aviary hens had a higher proportion of pecks directed to feeding, preening, object and litter pecking, aggressive pecking and feather pecking. Within free-range systems, increased range use is strongly associated with a reduced risk of injurious pecking (Green et al., 2000; Nicol et al., 2003; Lambton et al., 2010).

Early identification of the onset of injurious pecking is critical to manage this problem. Early warning signs which may precede signs of feather damage include increases in hen vocalisations (with more squawks) (Bright, 2008) and automated detection of overall flock movement patterns (Lee et al., 2011).

Apart from beak-trimming, the most commonly used management strategy to reduce IP is to reduce light intensity because SFP is increased under high indoor light intensity (Drake et al., 2010; Mohammed et al., 2010) (although paradoxically reduced by increased range use in far higher natural light conditions). Long-term housing under low light conditions can provoke other welfare problems including eye problems, difficulties in judging flight distances and disruption of social recognition (reviewed in Nicol et al., 2013). Another potential strategy might be to spray the feathers of birds with an aversive-tasting substance such as quinine salt, clove or garlic oil (Harlander-Matauschek et al., 2008; Harlander and Rodenburg, 2011). Laboratory tests showed that this was highly effective in reducing the tendency of hens to peck at isolated feathers but it might be difficult to implement commercially and it might have adverse effects on normal self-preening behaviour. It might also taint the eggs.

It is clear from the studies reported above that the risk factors for IP are multi-factorial. Prevention and reduction of this problem therefore requires a multi-factorial response and there is good and growing evidence that “packages” of preventive measures can significantly reduce all types of IP on commercial farms. For example, Zimmerman et al. (2006) and Nicol et al. (2006) in a study of 36 ST non-cage flocks found a significant reduction in IP and improved plumage condition in flocks that implemented a policy of lights-off in nest boxes, change from bell drinkers to nipple drinkers; de Haas et al. (2014a) found that an adjusted policy providing radios, pecking blocks and a choice of both nipple drinkers and round drinkers significantly reduced SFP on 35 commercial farms. Lambton et al. (2013) identified 46 management strategies that were expected to reduce feather-pecking and supported the implementation of these on farms through facilitated discussions with the farmers. The 53 intervention flocks employed more of the management strategies than the 47 control flocks and as a result had significantly improved plumage condition. Irrespective of whether flocks were intervention or control flocks, the more management strategies employed by the farmer the greater the benefit (Lambton et al., 2013). The management strategies described in Lambton et al. (2013) are now available as booklets for farmers and can be found at www.featherwel.org. The wider UK egg industry has supported these efforts to reduce feather loss in hens (‘Code of Practice for Lion eggs’, section I5: www.britisheggindustryCouncil.co.uk/download/LCoPV7.pdf).

Mullan et al. (2016) were able to assess the impact of a package of industry initiatives designed to improve plumage condition in UK free-range flocks in a study that included 830 farms in Year 1 and 743 farms in Year 2. A majority of farmers reported that they had implemented new management strategies on their farms in Year 1, and rates of feather loss correspondingly improved by Year 2, with, for example, severe feather loss on the back and vent regions decreasing from 12.6% to 8.3%. The strength of evidence that such packages of measures can be effective has led to industry adoption of management strategies specifically designed to reduce IP in non-cage flocks (Lion Code, www.featherwel.org).

LH3.5c Injurious cloacal (vent) pecking and cannibalism

Vent pecking is an extremely serious form of injurious pecking with very high levels of associated mortality. It occurs sporadically and unpredictably and there is only limited research on this topic.

Vent pecking is directed to the tissue surrounding the cloaca of another bird, whilst cannibalistic behaviour is the term used for pecks directed to other areas of skin and tissue (Savory, 1995). Vent pecking is an extremely serious form of injurious pecking because it can lead to rapid victim death and because outbreaks of vent pecking are unpredictable (Yngvesson et al., 2004; Lambton et al., 2015). It is not clear why some birds initiate cannibalism and why others become victims. Yngvesson et al. (2004) found no evidence that, during oviposition, victims of cloacal cannibalism exposed their cloacal mucosa any more than control birds. There is some evidence that, as for feather pecking, cannibalism can spread via social learning (Cloutier et al., 2002).

Overall, relatively few studies have attempted to disentangle specific risk factors for vent pecking and cannibalism separately from risk factors for SFP. The best information available suggests that low protein and low fibre diets have a strong influence on the occurrence of vent pecking-related mortality (Hartini et al., 2002) and other risk factors are illuminated nest-boxes, which may increase the visibility or attractiveness of the vent as a pecking target, the use of bell drinkers, early onset of lay, a higher number of diet changes during the laying period (Pötzsch et al., 2001), the provision of pelleted feed and certain configurations of perch provision (Lambton et al., 2015).

LH3.5d Aggressive pecking

Aggressive pecks occur during competition for resources, when unfamiliar birds meet, or when dominance relations are being established. Although feather pecking is often described colloquially as aggression, the two forms of pecking have different appearances and different underlying motivations. Aggressive pecks are usually directed towards the head region of another bird whilst feather pecking is directed primarily to the back and tail regions. Low correlations have been reported between feather pecking and aggressive pecking (Bessei et al., 2013). Birds that are able to avoid aggressive encounters are not always able to avoid receiving feather pecks.

Aggressive behaviour is not a substantial welfare concern, occurring infrequently in non-cage and cage systems, with actual fights uncommon (Freire and Cowling, 2013). Aggressive threats and pecks occur at rates of less than one per bird per hour in commercial flocks (Hughes et al., 1997; Carmichael et al., 1999; Nicol et al., 1999; Oden et al., 2000) but can

be higher during the process of hierarchy formation in smaller flocks of birds (Nicol et al., 1999). Aggression can also be localised at points of resource competition (e.g. just outside nest boxes (Lentfer et al., 2013) and so house designs that minimise local crowding will be generally beneficial.

LH3.6 Relationships between feather pecking (FP) and other traits

Feather pecking is often associated with higher levels of stress, fearfulness and activity but causal relationships are not always clear.

If strong relationships between FP in young chicks and later adult FP were confirmed in commercial strains, then early screening programmes could be developed. Currently, however, predictive correlations between chick and adult behaviour are either too weak or too uncertain to support such investment. Prospective studies have produced mixed results. Some have reported poor correlations between relatively-easily measured traits (such as fearfulness and exploratory tendency) and later FP behaviour or plumage condition (Albentosa et al., 2003; Hartcher et al., 2015b), whereas others have described significant relationships with these traits (Uitdehaag et al., 2008; de Haas et al., 2014a; 2014b).

Prospective studies are time-consuming to conduct and so there is more research examining general characteristics associated with feather pecking. This work could potentially identify traits or mechanisms that could be targets for genetic selection. Most studies have been conducted on experimental lines, particularly lines of birds that were originally divergently selected in Denmark for high or low FP behaviour (Kjaer, 2009). Birds from these lines, selected for *increased* FP also show greater stress responses to physical restraint (Kjaer and Guémené, 2009; Kjaer and Jorgensen, 2011), fearfulness (Rodenburg et al., 2004; 2010); locomotor activity (Kjaer, 2009; de Haas et al., 2010); foraging behaviour (de Haas et al., 2010), altered patterns of serotonin release and dopamine receptor type (Flisikowski et al., 2009; Kops et al., 2014) and improved egg weight, shell thickness and feed efficiency (Su et al., 2006) compared with LFP birds. The HFP birds are also more likely to eat feathers that have been removed than are LFP birds (Meyer et al., 2013; Bøgelein et al., 2014), but are less likely to persevere in certain operant tasks (Kjaer et al., 2015). Individual birds from these selected lines show low correlations between their tendencies to either feather peck or perform aggressive pecks (Grams et al., 2015), although some genetic correlations between these traits have been reported (Bennewitz et al., 2014).

Traits linked with FP have also been studied in a separate population of birds which were incidentally found to differ in FP tendency (Riedstra and Groothuis, 2002; van Hierden et al., 2002; Rodenburg and Koene, 2003). These birds also show positive associations between FP and locomotor activity (Rodenburg et al., 2004) and altered serotonin turnover in the severe peckers (van Hierden et al., 2002; Kops et al., 2013). Birds selected for low group mortality due to cannibalism showed lower fear levels towards humans (Nordquist et al., 2011).

LH3.7 Feather loss due to abrasion

Injurious pecking is not the only cause of feather loss and damage. Abrasion against the sides of cages can also lead to feather loss, such that overall feather cover on the wings or the belly is worse in hens from conventional and furnished cages than in birds from non-cage systems (Blatchford et al., 2016). Abrasion can be a significant economic and welfare problem, with loss of plumage resulting in higher feed intake to maintain body temperature, particularly in cool climates. Plumage damage that occurs as a result of abrasion is usually found on the underside of the neck, the primary wing feathers and the tail (Rodenburg and Koene, 2004). Some studies have reported similar abrasion in furnished and conventional cages (Appleby et al., 2002). Feather cover may be better when group sizes are small (less than 10) in furnished cages (Guémené et al., 2004). The design of the furnished cage, in particular perch and feeder height, may be involved in improving plumage by reducing the amount of stepping on other hen's backs (Freire et al., 1999; Appleby et al., 2002).

LH3.8 Foot health

Foot disorders are relatively common occurrence in laying hens housed in all systems. Skin thickening and infection of the foot causes discomfort and may be painful.

The physical environment should provide hens with a comfortable floor to walk on, perches to rest on and a safe environment to move around in that does not cause them injury. The floor substrate should enable foot health to be maintained by not damaging the foot pad or allowing dirt/manure build-up (which leads to diseases like bumble foot). Furthermore the hens should be able to scratch on a suitable hard surface to maintain a short claw length. Long claws can become trapped leading to injury, and can cause scratches, wounds and an increased risk of infection to other birds. Conventionally caged hens are more susceptible to elongated and damaged claws than hens in FCs (e.g. Onbaşilar et al., 2015) as they are unable to scratch and forage – abrasive materials may be fixed to the front of the cage to reduce the risk but are often not effective or fitted. However, Vits et al. (2005) concluded that claw shortening devices worked effectively to produce short claws in a range of different FC and small group housing systems.

Hyperkeratosis (thickening of the skin on the foot pad) is a common condition in commercial laying hens and it can precede or be accompanied by bacterial infections leading to swellings and abscess formation (known as bumblefoot). In one small-scale study, hens with foot pad dermatitis were faster to jump or fall from an elevated perch than healthy birds,

suggesting discomfort associated with this condition (LeBlanc et al., 2016). Weitzenburger et al. (2006b) found moderate hyperkeratosis and/or superficial epithelial lesions in 21% of hens, severe hyperkeratosis with deeper lesions and swelling in 6% and very severe hyperkeratosis, deep and large lesions and substantially swollen foot pads in 2% of hens from FC systems. Rönchen et al. (2007) found moderate hyperkeratosis in between 4.2 and 9% of birds in FC and aviary systems. Hyperkeratosis was more common between the toe and claw for birds housed in a FC whilst hyperkeratosis of the sole occurred more in an aviary system. More foot damage (Appleby et al., 2002) and compromised gait scores (Li et al., 2016; Meng et al., 2017) are found in birds from conventional cages compared with birds from FCs. Blatchford et al. (2016) noted more foot damage in birds from conventional cages than aviaries but, as also noted by Dikmen et al. (2016), a greater lesion severity in the non-cage birds. Generally, the wire floors of cages are a risk factor for hyperkeratosis but exposure to dirty perches or litter increases the risk of bacterial infection. Heerkens et al. (2016b) found prevalences of 42% hyperkeratosis, 27.6% dermatitis and 1.2% bumblefoot in hens from 47 non-cage MT flocks. However, in a promising development, the provision of ramps between perches has been shown to have a strongly significant beneficial effect in reducing foot lesions in non-cage MT systems (Heerkens et al., 2016a).

Wire or slatted floors enable droppings to pass through and hence are more hygienic than litter floors: they are commonly used in cages and in raised areas of group housing. Plastic flooring appears to have negative effects in comparison with wire mesh flooring, being associated with reduced plumage quality (Whay et al., 2007; Heerkens et al., 2015) and higher mortality and prevalence of wounds (Heerkens et al., 2015).

Toe pecking is an occasional and sporadic problem in laying hens, with a far lower prevalence than other forms of injurious pecking, but with negative consequences for foot health (Krause et al., 2011). Birds that receive toe pecks also show signs of elevated fearfulness (Krause et al., 2011).

LH3.9 Eye abnormalities

Eye abnormalities were lower in birds from non-cage systems than either furnished or conventional cages at 52 weeks of age (Blatchford et al., 2016) although this effect was not apparent when birds were re-assessed at 72 weeks.

LH3.10 Haemorrhagic fatty liver syndrome (HFLS)

HFLS is predominantly a condition seen in caged hens with little opportunity to exercise. It is associated with morbidity and reduced welfare.

This condition, abnormal accumulation of lipid in the liver, is due partly to inappropriate diet and partly to lack of exercise. The *ad libitum* provision of low protein, high fat diets (Rozenboim et al., 2016) can lead to excess storage of fats in the liver. The livers of laying hens become putty coloured owing to contents of up to 70% lipid (mostly triglyceride) and they also haemorrhage. Excessive abdominal fat is seen, and the kidneys are often pale and swollen. Mortality is generally low, but morbidity is high and egg production may fall. It is more common in conventionally caged layers which cannot exercise to use up the excess energy (Kaufmann-Bart and Hoop, 2009). Hens in conventional cages are often heavier than hens in non-cage systems (Sherwin et al., 2010), even when matched for breed and age (van Loon et al., 2004; Yang et al., 2014; Regmi et al., 2016a). In furnished cages, between 46% and 54% of hens show signs of fatty liver disease (Weitzenburger et al., 2005b). The importance of exercise as a protective factor against harmful fat deposition patterns is shown by studies that report lower triglyceride levels in free-range hens than in caged hens (Yang et al., 2014), lower abdominal fat deposits in caged hens provided with perches (Jiang et al., 2014) and lower abdominal and liver fat deposits in hens from aviary systems than hens from furnished cages (Rönchen et al., 2008). Simply providing perches in conventional cages was insufficient to alter liver fat deposition and improve liver function (Jiang et al., 2014).

LH3.11 Parasitic infections

Most parasitic infections in hens can be prevented or controlled with appropriate veterinary medication. The control of mite infestations is, however, a substantial challenge and threat to the welfare of laying hens.

LH3.11a Mites

Mite infestation can result in serious welfare problems for hens, causing discomfort, disturbed sleep, anaemia and death. The prevention and control of mite infestation is difficult and further research on control methods is needed. Hens with intact beaks are better able to remove mites from their own plumage.

The red mite, *Dermanyssus gallinae*, (with a worldwide distribution but rare in North America) and the Northern fowl mite, *Ornithonyssus sylviarum* (in North America) pose significant welfare problems for laying hens. Red mite infestation can result in hens becoming restless, with higher preening and head scratching rates during the day and at night (Kilpinen et al., 2005). Infested birds are also more likely to feather peck, they are physiologically stressed with levels of adrenalin (Kowalski and Sokal, 2009) and plumage quality deteriorates (e.g. Heerkens et al., 2015). Eventually birds will become anaemic and less productive and can die if left untreated (Kilpinen et al., 2005). Red mite is therefore a serious welfare problem and can also be a vector for the transmission of other diseases. The effect of the Northern fowl mite on bird

welfare is less clear, with experimental infections having no effects of infestation on comb colour, comb temperature, feather cover, or bodyweight but some negative effects on the birds' skin (Vezzoli et al., 2016).

Red mites spend most of their lives in refuges within a poultry house. They aggregate in clusters and locate the host birds using a variety of cues, feeding on the hens' blood for short periods (usually at night) before returning to the refuge. The prevalence of red mite is lower in cage systems. As the complexity and amount of 'furniture' in the house increases, so does the risk of red mite infestation, as the mites have more places to live undetected. However, a counter influence is that the provision of good, fine-particulate substrate that enables birds to express full dust-bathing behaviour can aid mite control (Vezzoli et al., 2015a). In organic production systems, diatomaceous earth can be mixed with other dust-bathing substrates to suppress mite infestations (Murillo and Mullens, 2016). In non-organic systems, control remains dominated by the use of synthetic acaricides, although resistance and treatment failure are widely reported, particularly as it is hard to treat every part of a complex housing system with birds *in situ*. New approaches to control are an area of urgent current research, including biological control, barrier methods, vaccination, and the use of essential oils (e.g. George et al., 2010), although the efficacy of these methods is variable and some have potential side-effects for birds. Given these challenges, it should also be noted that birds with intact-beaks are far better able to reduce both lice and mite infestations by preening (Mullens et al., 2010; Chen et al., 2011). Hot blade trimming compromises effective preening action to a far greater extent than infra-red trimming (Murillo and Mullens, 2016).

LH3.11b Coccidiosis

Coccidiosis is a welfare problem that causes intestinal inflammation and severe morbidity and mortality. It has historically been controlled by the use of anti-coccidial drugs. However, most pullets are now vaccinated rather than medicated, and there is renewed interest in developing fully effective (and cost-effective) vaccines.

The welfare impact of coccidiosis on poultry is substantial because the potential for enteric disease or poor thrift is universal. Control of the species of the protozoan parasites *Eimeria* and *Tyzzeri*, which cause coccidiosis, relies on vaccination, or use of scrolling generations of antiparasitic drugs (coccidiostats or coccidicidal drugs) which become ineffective as the parasite develops resistance. Because coccidia produce resistant oocysts, which can persist in the environment for long periods, coccidiosis is very difficult to eliminate from intensively farmed poultry and particularly from outdoor areas which cannot be effectively disinfected. Lunden et al. (2000) found a prevalence of coccidiosis of 19% from 57 flocks and 31% of 26 farms and also found that the risk of coccidiosis was not decreased by the practice of raising pullets without coccidiostats, ostensibly to increase their immunity. Contrary to belief, coccidiosis is an emerging issue in caged flocks, and not only a problem for birds with litter or outdoor access (Price et al., 2014). A particular challenge for caged flocks is that chicks ingest highly variable doses of the live vaccine when administered by spray. Effective flock vaccination depends on subsequent oral-faecal transmission between birds and this is harder to achieve in wire-floor systems (Price et al., 2016). Indeed, this provides another line of argument in favour of the provision of foraging materials for caged birds. Most pullets are now vaccinated rather than medicated, but the development of new vaccination strategies is an important ongoing goal in a global climate which seeks to reduce the use of medication in agriculture, and where bans on the use of many anti-coccidial drugs have been imposed in many countries.

LH3.11c Worms

Hens with access to litter or outdoor areas are more likely to become infected with worms. Heavy infestations may cause welfare problems but hens appear to harbour minor worm burdens without adverse effects on welfare.

Hens in any husbandry system with access to the droppings of other birds may potentially become infected with a variety of parasitic worms with similar impacts of suppressed welfare and productivity. The most common infestations are with roundworm (*Ascaridia galli*) and caecal worms (*Heterakis* sp.). A survey of Swedish flocks, for example, found roundworm infection rates strongly related to housing system (Jansson et al., 2010) (Table LH8).

Table LH8: Roundworm infection rates over two years

Housing System	2004	2004	2008	2008
	Flocks (n)	Infection %	Flocks (n)	Infection %
Cages (mostly FC, some CC in 2004)	42	2.4	46	4.3
ST barn	72	27.8	42	28.6
MT aviary	36	16.7	46	52.2
Free range/organic	35	48.6	35	77.1

In agreement with this, Weitzenburger et al. (2005b) found no endoparasites in hens from FCs. Within non-cage systems, access to the outdoors appears to be a bigger risk factor than access to litter *per se* (Heckendorn et al., 2009; Maurer et al., 2009), although Papini and Cacciottolo (2008) detected evidence of *Heterakis* infection in 50% of faecal samples from a litter-based system in Italy. In some countries it is quite possible that all free-range birds are infected by the end of lay. Infection rates can be reduced but rarely eliminated by good pasture management practices (Maurer et al., 2013). One survey found eggs of at least one genus of nematode present in the faeces of all 19 UK flocks surveyed (Sherwin et al., 2013). Thapa et al. (2015) assessed the overall mean European prevalence of *A. galli* to be 69.5%, with a mean burden of 10 worms per hen. Surprisingly in this study, the overall time on pasture was negatively associated with infection. Similar infection rates for 12 organic flocks in Denmark were reported by Hinrichsen et al. (2016) who detected roundworm (*A. galli*) in 56.1% of birds sampled. The overall mean European prevalence of *Heterakis* spp. was 29%, with a mean burden of 16 worms/hen, and large variation between countries (Thapa et al., 2015).

The clinical welfare implications of helminth infection may depend on the age and condition of the hens. Sherwin et al. (2013) found no associations between worm burden and other welfare indicators. Papini and Cacciottolo (2008) noted no adverse clinical signs of *Heterakis* infection, and Kilpinen et al. (2005) noted only lower weight gain in hens infected with *A. galli*, with no changes in blood parameters or bird behaviour.

Parasites are developing resistance to anthelmintics, so traditional methods like pasture rotation and even regular replacement of litter indoors may be needed with consequential increased labour requirement. Hygiene barriers at house entrances were associated with a reduced risk of infection (Jansson et al., 2010). In Switzerland, rates of helminth infection have consistently dropped as management practices have improved (Kaufmann-Bart and Hoop, 2009).

LH3.12 Infectious diseases

Intensively housed poultry are susceptible to many infections, most of which can be prevented by intensive vaccination programmes. Birds with access to free-range systems are exposed to a greater risk of some infectious diseases.

The infectious disease challenge faced by laying hens may vary by country. Many infectious diseases are controlled by vaccination, with vaccines available for Marek's disease, infectious bronchitis, bronchitis variants, Newcastle disease, infectious bursal disease, avian encephalomyelitis, avian rhinotracheitis, infectious laryngotracheitis, egg drop syndrome, erysipelas, and infections caused by *Salmonella enteritidis* and *typhimurium*, coccidiosis (see LH3.11b), *Mycoplasma gallisepticum*, *E. coli*, and *Pasteurella multocida*. Not all flocks will receive all of these vaccinations, but in Europe pullets will receive most of these vaccinations during a short period of time during the rearing phase. Vaccinations can be given in drinking water, as a flock spray or by bird injection. The sheer number of vaccinations to be scheduled, the stress associated with handling and injection, and the side effects of some of the vaccinations (e.g. reduced immune function, Prandini et al., 2016) means that (although protective of long-term health) the vaccination programme itself can become a welfare challenge.

Birds in free range housing systems are the most susceptible to infectious disease because they have the greatest exposure to potential vectors of disease (wild birds, rodents, wild animals) and biosecurity is more difficult to maintain. For example, antibodies to *Erysipelothrix rhusiopathiae* (the infectious agent causing erysipelas) were significantly higher in free-range flocks than from all other housing systems. In agreement with this, the number of erysipelas outbreaks in Swedish flocks, recorded between 1998 and 2011, was highest in free-range, followed by other non-cage systems. No outbreaks were diagnosed in conventional cage or furnished cage systems (Eriksson et al., 2013). High prevalences of infectious diseases (e.g. erysipelas, fowl cholera (*Pasteurella multocida*), blackhead (caused by the protozoan *Histomonas*) and septicemic *E. coli*) are also reported in organic systems (van der Meulen et al., 2007; Stockholm et al., 2010). However, improvements in vaccination availability and attention to biosecurity and control strategies have resulted in decreasing levels of viral disease in Swiss flocks in the years following the ban on conventional cages (Kaufmann-Bart and Hoop, 2009). Zoonotic diseases caused by *Salmonella* and *Campylobacter* spp. are mostly a concern for human health, although subtle changes in competitive behaviour and flock movement patterns have been observed in experimentally infected birds (hens, Toscano et al., 2010; broilers, Colles et al., 2016) and so there may be bird welfare implications of these diseases that have not been fully evaluated. Studies that have orally inoculated hens with *Salmonella enteritidis* have not detected any increased pathogen shedding or colonisation in non-cage systems (De Vylder et al., 2009). Indeed one experiment found that hens in conventional cages continued to exude pathogen for a longer period than hens in FCs or non-cage systems (De Vylder et al., 2009), another study identified conventional cage housing as a specific risk factor for *Salmonella* shedding (Van Hoorebeke et al., 2010) whilst Wierup et al. (2017) found no evidence of increased *Salmonella* occurrence in indoor outdoor laying flocks. In a study of 4 free-range farms there was no apparent relationship between faecal corticosterone metabolite concentrations and the extent of *Salmonella* prevalence in the environment or faecal shedding by the hens (Gole et al., 2017). Jones et al. (2016) detected significantly higher proportion (95%) of CC hens testing positive for *Campylobacter* compared with FCs (91%) and non-cage (85%) birds housed on the same research farm.

LH3.13 Immune function

Immune function is compromised by stress. A newly emerging research area concerns the optimization of the chicken gut microbiota to enhance immune function.

Assessing immune function is difficult as measures of function will necessarily be affected by the antigens and pathogens that hens are exposed to. A study comparing the immune function of hens housed in CC, non-cage or FR systems found no clear differences in innate immune responses, but did note specific immune responses affected by housing conditions (Van Loon et al., 2004).

Stress can impact negatively on immune function. Indeed some researchers have suggested that certain immune measures (pro-inflammatory gene expression) provide a more robust measure of stress than more traditional measures such as corticosterone, as the immune measures are less sensitive to factors such as bird handling (Wein et al., 2017).

Specific studies have reported that hens in conventional cages (with generally high stress responses) are less resistant to experimental infection with *Salmonella* than hens from colony cages (de Vylder et al., 2009; Gast et al., 2013). A recent study also found many other measures of immune function (heterophil function, CD4+ and CD8+ T cell proportions and antibody production) were all improved in hens from furnished cages compared with hens from conventional cages (Matur et al., 2015). Pullets raised in FCs are also more resilient than pullets raised in CCs when faced with the stress of transportation, showing increased heterophil function, CD8+ T cell and antibody production (Matur et al., 2016). There is a genetic component to immune function too, with hens from lines selected for low mortality in group-environments demonstrating greater cell-mediated immunity (Fahey and Cheng, 2008b).

In non-cage systems, despite or because of the increased challenge from pathogens, immune function can be high (Shimmura et al., 2010b). For example, mRNA levels of IL-2 gene expression in the spleen was greater in free range than in caged hens (Yang et al., 2014), and antibody titres after vaccination were higher against infectious bronchitis virus and campylobacter in birds from aviaries than in birds from FCs, although birds from FCs showed a higher antibody response to Newcastle disease virus (Auerbach et al., 2014).

There is an emerging evidence base that feeding probiotics to laying hens may reduce reproductive pathologies (Shini et al., 2013), facilitate a better gut microflora (Forte et al., 2016a) and enhance some aspects of immune function. For example, dietary supplementation with *Lactobacillus acidophilus* was reported to enhance the production of antibodies against Newcastle disease virus (Forte et al., 2016b).

LH4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

Hens have behavioural needs to perform comfort movements, foraging and nesting behaviour, and there are negative welfare impacts if these behaviours cannot be performed. Hens also appear to have a need to perch at night, but further research is needed to establish whether this need is satisfied by providing elevated resting areas rather than graspable perches. Evidence of a behavioural need to dust-bathe is less clear.

Facility construction should account for poultry behaviour. In unconstrained and enriched pens, hens allocate their daylight time budget to many different activities, as shown in Table LH9. Different authors categorise standing, perching and resting in slightly different ways, but these activities combined tend to account for approximately half of the birds' time, with feeding and foraging activities.

Table LH9: Laying hen time budgets

Behaviour	Mishra et al., 2005	Channing et al., 2001	Shimmura et al., 2010a (FR birds)
	% Time		
Feeding/foraging	11.57	21.8	Not reported
Walking	10.86	8.7	11.8
Preening	4.18	6.9	Not reported
Dust-bathing	0.67	1.6	2.4
Scratching	0.98	5.9	2.3
Drinking	1.36	3.1	Not reported
Nesting	14.75	0.8	6.0

Behaviour	Mishra et al., 2005	Channing et al., 2001	Shimmura et al., 2010a (FR birds)
Standing	12.89	44.7 *approx. half of this on perches	Not reported
Perching	13.56	See above	Not reported
Resting	27.72	5.4	Not reported
Other (e.g. wing flapping, flying, feather pecking, aggression)	1.46	1.1	

Information about the unconstrained time budget of hens is a first step towards establishing their behavioural needs, but additional information is required on their strength of motivation to perform different activities when kept under managed conditions. Hens are highly motivated to perform comfort behaviours such as wing stretching, and the motivation to perform these behaviours increases during periods of restriction e.g. due to spatial confinement (Nicol, 1987).

LH4.1 Behavioural need for a nest

Internal motivation to seek a suitable nest site increases prior to oviposition. If a suitable nest site is located hens are highly motivated to sit and to show rudimentary nesting behaviours for up to one hour before they lay their egg. If a suitable nest site is not located, hens show signs of frustration and elevated measures of stress are observed.

There is an internal component to nesting motivation such that, approximately 1-2 h before oviposition, hens become increasingly active and restless and start to search for a suitable nest site. Potential nest sites are inspected closely before one is chosen for nesting and egg laying. Whilst nesting, hens alternate between sitting and (vestigial) nest building activities such as turning, floor scratching, and manipulating potential nesting materials such as pieces of straw. If such highly preferred substrates are absent, then almost any material will be pecked at and placed around the body. Hens have preferences for nests that can be moulded by their own bodies, but they will accept pre-formed nests, provided these permit some of the nest building activities mentioned above (Duncan and Kite, 1989). The majority of hens sit in the nest for between 17 and 25 min before oviposition (Cronin et al., 2005; Hunniford and Widowski, 2016), with total time spent in nests ranging from 23 to 65 min (Heinrich et al., 2015). Many studies have shown that hens have a high motivation to access a preferred nest, particularly as the sitting phase approaches, and this motivation has been measured by observing hens squeezing through narrow gaps (Cooper and Appleby, 1996) or pushing through weighted doors (Cooper and Appleby, 2003). In this latter study, at approximately 20 minutes prior to oviposition, hens worked at a higher rate for nest access than is seen for access to feed (after a 4 hour deprivation period). There have been mixed reports about the extent to which nest deprivation increases physiological stress. Yue and Duncan (2003) observed rapid pacing when access to an habitual nest was blocked, but no changes in egg shell calcium deposits. Cronin et al. (2012) found no increase in egg albumen corticosterone level when access to a nest box was prevented but Alm et al. (2016) found that exclusion from nests in furnished cages was associated with a marked increase in faecal corticosterone metabolites (from approximately 550 ng/g dry matter, to approximately 750 ng/g dry matter) and in heterophil:lymphocyte ratio (from 0.11 to 0.15). Corticosterone measured in egg yolk showed a more variable response, with a rise for a few days followed by a fall, whereas corticosterone measured in plasma showed the greatest increase after the period of exclusion had ended (Alm et al., 2016). If stress associated with nestbox exclusion is linked to the timing of nesting motivation prior to oviposition, then measures that integrate stress over a prolonged period of time may not be very sensitive in this context.

LH4.2 Behavioural need for a perch

Evidence for a behavioural need to perch is complex and the different components of perching have not been fully considered until recently. It seems that hens are highly motivated to seek elevated areas at night for roosting, but further research is needed to establish whether birds need to grasp a rounded pole with their feet, or whether roosting motivation is satisfied by elevated platforms or grids that may pose less of a risk of bone damage.

The evidence reviewed above suggests that perches have some benefits for bird health, encouraging stronger bones and reducing the risk of some types of foot condition. However, they also present an increased collision risk and so the costs and benefits of providing perches must be carefully weighed. A key factor is the strength of the birds' perceived need to perch. This is complicated by the fact that the concept of perching has at least 3 different potential meanings (EFSA, 2015). A bird may have a need to grasp a rod-like structure with its feet, to seek an elevated viewpoint, or to reach an elevated point with or without a view. In deciding what might count as a "perch" ideally these needs would be considered separately but until very recently, the scientific literature has not distinguished these possibilities.

LH4.2a Seeking elevation (at night): roosting

If perches are provided they are highly utilised at night for roosting (Olsson and Keeling, 2000). Brendler et al. (2014) found virtually 100% utilisation at perch heights of 90 cm or above in small experimental studies. On farm studies also demonstrate high night-time perch use in commercial flocks (Oden et al., 2002) with hens showing a preference to roost at the higher positions in aviaries and multi-tier systems (Campbell et al., 2016b), both on higher tiers and on more elevated perches within those tiers (Brendler and Schrader, 2016). More formal evidence of a high motivation for night-time roosting comes from studies showing frustration if access to perches is denied (Olsson and Keeling, 2000) or assessing the effort expended by hens. Olsson and Keeling (2002a) found that hens would work at 75% of their maximum capacity to reach an elevated perch. The motivation to seek an elevated area is reduced in caged hens by a competing motivation to avoid contact with the cage roof. Provided there is a minimum distance of approximately 20 cm between the top perch and the cage roof, hens prefer to roost at night on the highest perches available over a range of 6 to 36 cm but cage heights of less than 55 cm restrict hens' capacity to perch (Struelens et al., 2008c); Once hens have roosted there is no evidence that those in higher positions are any less vigilant than those on lower perches (Brendler et al., 2014).

LH4.2b Seeking elevation (daytime)

Daytime perch utilisation is far more variable than night-time roosting and formal motivational demand experiments have not been conducted. Daytime perching is thought to enhance hens' sense of security, with reduced vigilance and fearfulness observed at a flock level in flocks with perches compared to flocks without (Donaldson and O'Connell, 2012). The need to perch during the day can be influenced by the presence and behaviour of other birds. Being part of a larger group may reduce fearfulness in some individuals and reduce the perceived need to perch as an anti-predator response (Newberry et al., 2001). Competition for perch space in larger groups may also reduce individual perching duration so, in FCs, group size can reduce utilisation (Chen et al., 2014). However, social facilitation may play a counter-role in larger groups, and in other studies perching behaviour has been shown to increase with group size in FCs (Guo et al., 2012). Restricted cage height means that hens will often select lower perches than they would otherwise prefer (Rönchen et al., 2010; Chen et al., 2014).

LH4.2c Grasping

Grasping is the act of wrapping the toes around a (rod or stick) perch, via active or passive flexion of the toes. Chickens have feet that are capable of grasping. However, in comparison with many other species, the feet of chickens are less specialised for grasping, as chickens make greater use of their feet for locomotion and for scratching for food (Sustaita et al., 2013). Schrader and Muller (2009) offered hens different combinations of high (60 cm) or low (15 cm) "graspable" perches, or high or low "non-graspable" flat plastic grids, for night-time roosting. Hens showed a strong preference for high structures over low, and a weaker preference for perches over grids presented at the same height. When forced to make a choice between high grids or low perches, birds selected on the basis of a preference for height. Further support for the predominance of the height preference comes from studies within commercial MT houses, that show hens' preference to roost on a high "non-graspable" tier is stronger than their preference to perch within a lower tier (Brendler and Schrader, 2016). Whether there is any separate "grasping" motivation has yet to be investigated.

LH4.2d The need for a perch

Although there is evidence that laying hens are frustrated if they are unable to access perches that they have previously used at night, evidence that hens "miss" perches if they have never been experienced is equivocal. When pullets or laying hens are housed in conventional or furnished cages either with or without the provision of a perch, no differences in stress response (plasma catecholamines, corticosterone, 5-HT and adrenal weight) have been observed in commercial breeds (Barnett et al., 2009; Yan et al., 2013; 2014). Similarly controlled studies to examine stress responses have not been conducted with non-cage flocks.

The provision of perches can reduce aggression in small groups of hens (Cordiner et al., 2001). In non-cage flocks it would seem beneficial to allow highly-motivated night-time roosting on elevated structures, but these may be achievable by providing appropriately-designed grids, ramps and platforms that do not necessarily fit the common image of a "perch" but that do minimise risks of injury and fracture (Stratmann et al., 2015a; Heerkens et al., 2016a; Pettersson et al., 2017). Such provision may also be beneficial during the rearing period (see LH9). Within non-cage systems further research, to consider how hens use all of the structural elements provided, is still needed (Campbell et al., 2016b). It is also possible that the fear-reducing properties of perches could be met in other ways e.g. by providing ground-level covered areas or refuges (Freire et al., 2003).

If perches are provided they should be non-slip (Scott and MacAngus, 2004) (but of a material that minimises risk of red mite), and sufficiently wide (4-6 cm) to minimise pressure (Pickel et al., 2010; 2011a) and meet hen preferences (Struelens et al., 2009). Hens do not appear to have strong preferences based on perch colour (Chen and Bao, 2012) but they do prefer perches of rectangular or square shape (Chen et al., 2014). Square perches result in less pressure on the keel area (Pickel et al., 2011b) but experts recruited for an European Food Safety Authority (EFSA) workshop suggested that such perches should at least have rounded edges to avoid injury (EFSA, 2015). In FCs a minimum length per bird of

15 cm (not including cross-points) is required to enable most birds to perch at the same time. The length of perch space required in non-cage systems is not clear and will depend on the provision of other elevated structures, especially within MT systems. Scientific studies have not yet been conducted on the benefits of providing perches of *varying* widths and shapes to allow birds choice and to vary pressure points.

LH4.3 Behavioural need to forage

Foraging dominates the laying hen time budget and hens show a strong motivation for this behaviour in formal demand experiments. Restrictions on foraging increase the risk of birds directing their foraging behaviour towards other birds (resulting in injurious pecking LH3.5).

The provision of *ad libitum* feed does not remove the hens' need to engage in foraging behaviour. Indeed, in the presence of free food, hens may still choose to expend energy in a range of foraging behaviours, a phenomenon sometimes called contra-freeloading (Lindqvist and Jensen, 2008; 2009). The additional energy expenditure would, under natural conditions, be balanced by increased information about patterns of food availability in the environment. Domestication has reduced, but not eliminated, the hens' strong motivation to forage (Lindqvist and Jensen, 2008; 2009). One way of quantifying the importance of foraging resources is to employ consumer demand theory to quantify the hens' motivation relative to other, known, yardsticks such as demand for food. Gunnarsson et al. (2000b) investigated the demand of caged hens for a litter substrate and found that all subjects would work (by pecking a key on schedules that varied from 5 pecks to 200 pecks for each resource access) to obtain straw.

LH4.4 Behavioural need for dust-bathing

Dust-bathing is a behaviour that occurs in healthy hens under good environmental conditions and is therefore a good marker of high welfare. It plays an important role in plumage maintenance and ectoparasite control. Dust-bathing motivation is intermittent and dependent on environmental cues. The role of consistent internal motivation is less clear than for foraging, stretching, nesting and night-time roosting.

Dust-bathing shows a clear diurnal rhythm and under unrestricted conditions, hens dust-bathe about every 2 days (Olsson and Keeling, 2005). Dust-bathing functions both to remove feather lipids thus improving plumage insulation (Olsson and Keeling, 2005), and to remove ectoparasites (Martin and Mullens, 2012; Murillo and Mullens, 2016). The presence of a suitable substrate is an important stimulus for eliciting dust-bathing, and hens seem to prefer substrates with a fine structure and low lipid content, such as sand and peat which are better at penetrating and cleaning the plumage (de Jong et al., 2007; Scholz et al., 2010; 2011). Preferences depend partly on early experience (Olsson et al., 2002; Orsag et al., 2012) but can be revised by exposure to new substrates in adult birds (Nicol et al., 2001; Wichman and Keeling, 2009), and fine-grained substrates are readily accepted by inexperienced adults (Wichman and Keeling, 2008). Dust-bathing is further increased if the substrate is combined with light and heat.

Full sequences of dust-bathing comprise many elements, including beak raking, turning, wing shaking and scratching, followed by stationary lying interspersed with further rubbing and scratching movements before the hen stands and shakes (Olsson and Keeling, 2005). The performance of a full sequence of dust-bathing returns motivation to baseline and is a good indicator of positive welfare. In many commercial settings, particularly in FC environments, incomplete sequences of dust-bathing are observed (LH5.2).

The extent to which dust-bathing in a managed environment (with assumed control of ectoparasite levels) can be considered to be a behavioural need is still a matter for debate. Dust-bathing appears to be a low-resilience behaviour that is forfeited when other needs are more pressing. It has been suggested that chickens allocate time to this behaviour as and when the opportunity arises (Widowski and Duncan, 2000). Experimental studies show it to be a lesser priority than other behaviours (e.g. Petherick et al., 1993; Keeling, 1994) and compensatory rebound in this behaviour is not seen in all studies (e.g. Guesdon and Faure, 2008). However, hens are more likely to choose dust-bathing substrates after a period of restriction (Arnold and Hemsworth, 2013). The opportunistic timing of dust-bathing may also explain why many birds are often seen to dust-bathe simultaneously in groups.

LH4.5 Social behaviour

Hens are social birds and their behaviour is strongly influenced by others. Aggression and fearfulness are reduced when hens are kept with other familiar birds. Hens in small groups distinguish between individuals and form social hierarchies, but do not appear to form particular attachments. Hens in large flocks adopt different social strategies to avoid aggression.

Under natural conditions, chickens live in social groups where they recognise and respond differentially to other individuals. The exact nature of the group alters as chicks are hatched, reared and disperse, or as food reserves and seasons change. A typical chicken group size cannot be specified too closely, but unconstrained chickens are often seen associating in groups of between 3 and 30 individuals. Once group size exceeds around 100 individuals, chickens cannot distinguish between familiar and unfamiliar birds (D'Eath and Keeling, 2003).

Adult birds housed in small groups (of less than about 100) prefer familiar breeds, and familiar birds over unfamiliar birds and tend to direct aggression towards unfamiliar individuals (D'Eath and Keeling, 2003; Vaisanen and Jensen, 2004). The individual identity of familiar companions is also distinguished (Abeyesinghe et al., 2009) but there is no evidence that adult hens form specific preferences for other individuals ("friends") (Abeyesinghe et al., 2013). Young birds are stressed by social isolation (Weldon et al., 2016) but there is no evidence that adult hens (at least under non-threatening conditions) have a preference to be with other birds at all (Arnold and Hemsworth, 2013).

Familiarity, and also the individual identity of familiar conspecifics, is primarily assessed using visual cues (Abeyesinghe et al., 2009). Familiar chickens in small groups establish dominance hierarchies, initially using threats and aggression. Aggression decreases more rapidly when pullets are placed in CC or FC systems at the start of lay than in non-cage systems (Shinmura et al., 2006a). Once the hierarchy is established, subordinate birds are able to move within close proximity of more dominant individuals and exhibit normal behaviours such as dust-bathing (Shimmura et al., 2010a). Aggression was higher in groups of 10 pullets than in groups of 40, where birds had more space to avoid others (Liste et al., 2015). If aggression does occur in small groups it can also be reduced by providing elevated structures such as perches that enable subordinate birds to move away from dominant birds (Cordiner et al., 2001), and aggression (as indicated by comb wounds) is reported to be lower in FCs than CCs (Hetland et al., 2003), likely for this reason.

Increasing group size makes it more difficult for hens to distinguish familiar and unfamiliar birds (D'Eath and Keeling, 2003) and behavioural strategies are altered. In larger groups fights are avoided by attending to simple cues (e.g. avoiding heavier birds) rather than by remembering established relationships (Pagel and Dawkins, 1997) but hens may avoid performing certain behaviours such as dust-bathing in the close proximity of unfamiliar birds (Shimmura et al., 2010b).

Aggression in hens (not to be confused with injurious pecking) is often triggered when an energetic behaviour is directed towards another bird, and interpreted as a threat (Rodriguez-Aurrekoetxea and Estevez, 2014) and is more likely to occur in medium-sized groups of birds (approx. 100 to approx. 500) when social hierarchies are not fully established. In larger commercial non-cage flocks of hens aggression generally occurs at low levels (see LH5.3).

A degree of synchrony in the performance of behaviours such as feeding, dust-bathing and resting is a common occurrence in small and large flocks of chickens (Collins et al., 2011). Synchrony can arise because each individual responds independently but in the same manner to the current environment. Thus, the majority of birds feed together at every run of the chain feeder, and most laying hens fly up to the perches in an aviary system at lights out. In these various studies, synchronous behaviour of the chickens occurs largely because the environment provides circadian or other cues that influence individuals in the same way. Chickens can also attend to and match the actions of their companions. Hoppitt et al. (2007) for example, found more synchrony in behaviour within groups than between groups housed in the same environment. Both of these effects can lead to spatial clustering (Collins et al., 2011) unless space is constrained to a point where hens try to maximise their distance to other birds (Albentosa and Cooper, 2005).

Facilities should account for the tendencies of hens to synchrony or cluster. For example, the length of feed troughs should ideally be sufficient to enable all birds to feed at once (Knierim, 2000). Mathematical modelling based on the average bird widths suggested that this could only be achieved by a 10% reduction in stocking rate for white hybrids and a 20% reduction in stocking rate for brown hybrids (Briese and Spindler, 2013). At normal FC spatial allowances of 750 cm²/bird, birds will have, at times, to share feeder space. This may be possible and will not necessarily result in aggression (Thogerson et al., 2009a; 2009b). At equivalent stocking rates, sharing of space is facilitated by keeping birds in larger cages and larger group sizes (Appleby, 2004).

LH5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

Behaviour in conventional cages is severely constrained with evidence of negative effects on welfare. Behaviour in furnished cages is also constrained but to a lesser degree. There can be problems with resource use and competition within the furnished cage environment. Behaviour in non-cage systems is not directly constrained but levels of problematic behaviours such as injurious pecking, collisions and smothering are often greater.

LH5.1 Behaviour in conventional cages

The spatial restriction of the conventional cage prevents or constrains the performance of most comfort movements, and there are no resources to meet the birds' roosting and nesting needs. A limited amount of foraging can take place in the feed trough.

At the high stocking rates and small cage sizes typical of a conventional cage, hens are effectively prevented from performing even simple locomotor and comfort movements. In a classic paper, Dawkins and Hardie (1989) recorded the unrestricted behaviour of brown hybrids. They presented the following ranges of space occupied to turn around (540 to 1,006 cm²), stretch wings (653 to 1,118 cm²), wing flap (860 to 1,980 cm²), preen (814 to 1,270 cm²), and ground scratch (540 to 1,005 cm²). More recently, in a video kinematic study of white hybrid layers, Mench and Blatchford (2014) determined the space required by hens to stand (563 cm²), turn around (1,315 cm²), lie down (318 cm²), and wing flap

(1,693 cm²). The mean heights utilised were, for standing (34.8 cm), turning (38.6 cm) and wing flapping (49.5 cm). Lohmann Silver hens occupy 545 cm² when standing (Briese and Hartung, 2009).

These basic figures do not take into account the capacity of hens to share space (a factor that increases with increasing cage and group size at the same stocking rate, Appleby (2004) which could reduce spatial requirement. But neither do these figures take into account the tendency of hens to cluster and perform behaviours in synchrony (LH4.5), attributes which could increase spatial requirements. Savory et al. (2006) observed hens in groups of 5 or 6 in adjustable test pens at 600, 2,400, 4,800, 7,200, 9,600 and 12,000 cm²/bird. The greatest constraints were observed at 600 cm²/bird compared with 2,400 cm²/bird, but the authors concluded that any space allowance of less than 4,800 cm²/bird imposed some constraint on behaviour.

Observations taken of the behaviour of birds in commercial conventional cages confirms that many behavioural activities are constrained. Rhim (2014) compared birds housed at 420, 660 and 940 cm²/bird (group size 5 in all treatments) and found that comfort movements such as preening, walking and stretching were increased at higher spatial allowances, whilst sleeping and inter-bird pecking were reduced. Appleby et al. (2002) noted more comfort behaviour by hens in small furnished cages than hens in conventional cages. A meta-analysis of 35 separate scientific studies showed that comfort behaviour is performed at a far lower level in conventional cages than other systems (Freire and Cowling, 2013), a finding confirmed in other reviews (Lay et al., 2011) and in more recent papers from China (Li et al., 2016; Meng et al., 2017). Li et al. (2016) reported more walking in all types of FC compared with CC, and more preening, nesting, scratching, perching and social behaviour in some designs of FC compared with CC. Hens do not adapt to spatial restriction, their motivation to do the restricted behaviours shows a compensatory rebound which increases with duration of confinement (Nicol, 1987).

The lack of resources such as any litter material means that hens cannot show dust-bathing behaviour in conventional cages, although their motivation to do increases with time as indicated by rebound levels of dust-bathing if litter is provided after a period of restriction in a conventional cage (Colson et al., 2007).

Fear responses to novel objects (Colson et al., 2006) and fear responses indicated by tonic immobility (Li et al., 2016) are greater for hens in conventional cages than hens in aviaries (Colson et al., 2006).

The production of hens kept at a space allowance of 361 cm²/bird is lower than that of birds kept at 482 cm²/bird (Anderson et al., 2004) but no differences in feeding behaviour were noted for hens kept at space allowances between 458 and 465 cm²/bird (Cook et al., 2006).

LH5.2 Behaviour in furnished or colony cages

Colony cages provide sufficient space to enable hens to show comfort behaviours such as stretching and preening, although other behaviours such as wing flapping are still spatially constrained. Nests and perches go some way to satisfying nesting and roosting motivation but designs could be further improved and layout needs to be considered to avoid competition. The scratching area appears to be insufficient for full expression of foraging and dust-bathing behaviour.

Compared with conventional cages, hens in furnished or colony cages show lower levels of aggression (Hetland et al., 2003; Shimmura et al., 2006), and more comfort behaviour (Shimmura et al., 2006; Shimmura et al., 2007a; Pohle and Cheng, 2009a). They are also more able to dissipate heat during hot weather by adopting appropriate postures (Guo et al., 2012), an effect that halved mortality in one study (Guesdon and Faure, 2004).

Colony cages provide some of the resources needed to satisfy hens' behavioural needs, but in a rather minimal form. Although, as noted in section LH5.1, behaviour is far less constrained in a furnished cage than a conventional cage, competition (Shimmura et al., 2007c) and constraints on space can affect full behavioural expressions. Albentosa and Cooper (2004) observed no wing flapping at all in small furnished cages designed to house 8 hens (at 762 cm²/bird), even when stocking rate was reduced to 2 birds/cage (3,048 cm²/bird). The rate of performance of other comfort behaviours such as wing stretching and tail wagging decreased with higher stocking rate.

Most hens will use the enclosed nest area of a colony cage for egg laying (Abrahamsson and Tauson, 1997; Appleby et al., 2002; Cooper and Appleby, 2003), although a minority prefer to lay eggs in more open locations (Zupan et al., 2008) and occasionally birds end up using nests as a refuge area (Shimmura et al., 2008a). Nest usage has improved since early studies (e.g. 43-68%, Guesdon and Faure, 2004) and now nest usage rates of over 85% are the norm in published studies from Europe, Turkey and Canada (e.g. Wall, 2011; Guinebreiere et al., 2013; Onbaşlı et al., 2015; Alm et al., 2016; Hunniford and Widowski, 2016 (for cage-reared birds). As furnished cages designs have continued to improve, nest usage levels of over 95% have been reported (Platz et al., 2009; Huneau-Salaun et al., 2011b; Bovera et al., 2014). However, detailed attention to design is important and nest use could be further encouraged by the use of artificial turf and other small modifications (Wall et al., 2002; Struelens et al., 2005; Guinebreiere et al., 2013). Plastic nest floors are linked with higher mortality in furnished cages (Guinebreiere et al., 2013). Not all types of nest floor or curtain design have yet been compared although some UK funded studies are ongoing. Hens in FCs may need more than one nest area to show fully settled nesting behaviour (Hunniford and Widowski, 2017).

Perches are widely used for night-time roosting but have mixed effects on plumage condition, with improvements to feather cover on the back, but reduced condition of the breast and tail areas (Hester et al., 2013). A small number of hens lay whilst perching, which can result in dirty and broken eggs. This problem may be reduced if low (7 cm vs 24 cm) perches are used (Tuytens et al., 2013) as the resultant increased disturbance of daytime perching leads to a greater utilisation of the nest (Tuytens et al., 2013). However, this solution is something of a trade-off and it might be better to try to improve the attractiveness of nests for the perch layers. That said, the optimum height of a perch within a cage environment is not known. Low perches are used for night-time roosting and may even be preferred by birds in cages where the distance from the perch to the cage ceiling is a constraint (Chen et al., 2014). The provision of perches within FCs reduces the number of birds that sleep in the nest and improves food conversion efficiency (Valkonen et al., 2009). In calculating the perch length required within a FC, it should be recognised that cross-points cannot be fully used (Struelens et al., 2008a).

Providing an area for scratching and foraging activities is also problematic. Most designs of colony cage include a mat placed over an area of wire floor where small amounts of feed are distributed but these behaviours are rarely expressed in their full form. In addition, Guinebreiere et al. (2012) found that rubber mats were readily destroyed and adding litter only increased wear and tear on the mat. Some cages deliver small amounts of feed as litter material onto an artificial-turf mat in the main area of the cage but this can be rapidly depleted and birds can be excluded from the scratching area by dominant hens (Shimmura et al., 2008a; 2008d).

Separate dust-bathing facilities are not generally available for hens in colony cages, and the provision of loose materials such as peat or sand is technically difficult and/or has adverse effects on air quality. In addition, individual birds have specific substrate preferences and their dust-bathing behaviour is influenced by previous experience (Olsson et al., 2002), so finding a solution that suits all birds is not straightforward. Floor-reared birds tend to show more dust-bathing in FCs than cage reared birds (Roll et al., 2008). Studies that have provided a separate dust-bath within a furnished cage have noted a binomial distribution in usage, with half of tagged birds using the facility very frequently or nearly every day, but the other half rarely if ever using it (Wall et al., 2008). In commercial designs of FC where no separate dust-bath is provided, hens are expected to dust-bathe within the matted area provided for scratching and foraging. This area is normally covered with an artificial turf mat, but these are not always well used for dust-bathing (Alvino et al., 2013; Lee et al., 2016; Louton et al., 2016). Average bout lengths of dust-bathing are approximately one third of the duration of bouts seen in non-cage litter systems (Platz et al., 2009). This lack of use is not due to social exclusion (Olsson and Keeling, 2002b) but rather to inadequate space and substrate provision. Hens in FCs with artificial-turf mats are more likely to perform sham dust-bathing on wire, and more likely to show more frequent but incomplete bouts of dust-bathing (Alvino et al., 2013; Louton et al., 2016) than hens in less constrained conditions provided with fine particulate substrates. Dust-bathing behaviour can be encouraged within a FC environment by, for example, increasing the size of the mats (Louton et al., 2016) or sprinkling quantities of feed, or powdered feed with smaller particulate size (Moroki and Tanaka, 2016b) on the mat. The frequency with which this is done produces a linear increase in dust-bathing behaviour (Lee et al., 2016) but still does not result in 'normal' dust-bathing behaviour, and this practice may not be considered a feasible management strategy by some producers. The relatively high lipid content of feed makes it a rather unsuitable substrate for dust-bathing (Scholz et al., 2014b). Rubber mats in the pecking and scratching area of the cage appear to be more accepted by hens for dust-bathing behaviour (Guinebreiere et al., 2015). Another promising approach may be to consider the use of modified floor types (Merrill and Nicol, 2005) or slightly friable (sand, or wood and oyster shell) blocks which stimulate dust-bathing (Guinebreiere et al., 2014) and would seem to have few negative effects on the overall house environment.

As group size increases within a colony-cage environment, indices of stress have been reported to increase (Scholtz et al., 2008a) but not to levels seen in small group furnished cages (Scholz et al., 2008a). In addition, birds within larger colonies (and larger cages) have more room for locomotion and movement (Weitzenburger et al., 2006a; Shimmura et al., 2009). Bovera et al. (2014) compared hens housed in groups of 25 or 40 (at the same 750 cm²/bird spatial allowance) and found no differences in mortality. They did not assess indices of stress but they did note that a slightly lower proportion of eggs laid outside the nests in the groups of 40 (1.9% vs 2.6%).

LH5.3 Behaviour in non-cage systems

Behaviour in non-cage systems is relatively unconstrained although individual birds may not access all areas of the house. Welfare problems of injurious pecking and smothering, and production losses due to floor eggs can arise. Good management of non-cage systems is challenging.

Non-cage systems provide sufficient space for all locomotor and comfort activities, and provide birds with access to the resources required for their priority behaviours – foraging, perching, nesting and dust-bathing. MT systems also provide birds with options for refuge if they are being attacked (Freire et al., 2003). The provision of a litter area for foraging may be one of the most significant benefits of a non-cage system. However, litter areas are not always easy to manage and can become compacted and damp, a risk that increases with stocking rate (Kang et al., 2016). The fear levels of birds with damp litter are higher than those of birds kept with dry, friable litter floors (Campo et al., 2009).

Aggressive behaviour is generally infrequent in non-cage systems. Actual fights are rare and one quantitative assessment of previous studies found the risk of aggressive pecking to be no greater than in caged systems (Freire and Cowling,

2013). However, a more recent paper reported greater feather damage on the head (likely caused by aggressive pecking) in aviary systems than in furnished or conventional cages (Blatchford et al., 2016). Aggressive threats and pecks occur at rates of less than one interaction per bird per hour in many large or commercial flocks (Carmichael et al., 1999; Hughes et al., 1997; Nicol et al., 1999; Oden et al., 2000; Zimmerman et al., 2006; Rodenburg and Koene, 2007). If aggression does occur it is most likely to do so at points of resource competition (Lentfer et al., 2013) and can be targeted at a minority of birds who receive a disproportionate amount of aggression (Estevez et al., 2003; Freire et al., 2003; Appleby et al., 2004). Their welfare is a cause of considerable concern. These victimised birds often scurry rapidly from one hiding place to another, their abnormal behaviour seemingly attracting further aggression as they attempt to find shelter under fittings or in nestboxes. They may rarely venture out for food and water due to the extreme risk of attack.

Bird distribution is not always even within a non-cage system (Channing et al., 2001; Lentfer et al., 2013) and individual birds may restrict themselves to certain locations within the house (Oden et al., 2000; Freire et al., 2003) though birds do not tend to stay in social subgroups. The risk of injurious pecking and cannibalism is higher in non-cage systems, particularly if hens have intact beaks, because a bird that engages in this harmful behaviour has access to many more potential “victims” than a bird in a cage.

Non-cage systems are associated with a higher occurrence of smothering problems (LH3.2).

If some hens do not use the nest boxes within a non-cage system then the resultant floor eggs are difficult to collect and likely to be dirty or broken. A small minority of birds appear to find enclosed nest boxes unsuitable for laying, such birds also appear to be more restless (Zupan et al., 2008) but just as motivated to reach an open nesting site as the majority of birds are to reach an enclosed nest (Kruschwitz et al., 2008). Increased pre-lay restlessness is not associated with elevated stress (Cronin et al., 2012) and may simply reflect a different nesting strategy adopted by a minority of hens. If some types or positions of commercially-provided nests are not accepted by hens, this can lead to crowding and gregarious nesting in the more preferred locations, particularly locations at the ends of rows or on the boundaries of outdoor pens (Clausen and Riber, 2012; Riber, 2012a; 2012b), with a likely concomitant increase in the risk of smothering. In the immediate period after the onset of lay, young birds are attracted to nests which are already occupied by other birds though, with time, this tendency towards gregarious nesting declines as individuals develop their own nest-box preferences (Riber, 2010). In commercial non-cage systems large group nests are the norm, despite the preference of many individual hens for smaller or partitioned nests, particularly during early lay (Ringgenberg et al., 2014; 2015b).

Improving nest box design e.g. with provision of preferred design features e.g. yellow nest walls (Huber-Eicher, 2004; Zupan et al., 2007), rubber or artificial grass rather than plastic nest floors (Buchwalder and Frohlich, 2011) and a relatively shallow slope of the floor (Stämpfli et al., 2011) are all features that hens prefer. The most important influence on nest selection, however, appears to be the provision of some form of nesting material (Freire et al., 1996; Struelens et al., 2008b). The sight alone of nesting material can trigger nesting behaviour in some birds (Hughes et al., 1995). Straw is preferred over peat or wood-shavings as a nesting material (Clausen and Riber, 2012). When hens nest in preferred locations their nesting behaviour is more settled and, contrary to the lack of association seen between restlessness and physiological stress during the pre-lay period, interrupted and restless nesting behaviour is associated with an increase in measures of physiological stress (Cronin et al., 2012). Accommodating hens' nesting preferences also has the potential to increase nest usage and reduce the proportion of eggs laid elsewhere. In many commercial systems nests have thick and opaque plastic strips (curtains) hanging over the nest entrance, providing an even greater degree of seclusion. The presence of such strips neither encourages nor discourages egg laying (Struelens et al., 2005) but does seem to result in more settled nesting behaviour (Struelens et al., 2008b). A closed front curtain provides the greatest degree of seclusion but limits important nest inspections that are made possible by curtain strips (Stämpfli et al., 2012). It should also be recognised that hens in non-cage systems have strong preferences for the nest boxes positioned at the ends of the row, independent of other features (Clausen and Riber, 2012). It may be that these are the most memorable positions and that hens use location cues to ensure they return to the same nest on subsequent days. However, attempts to assist hens use the same nest by providing more subtle visual cues were not successful (Ringgenberg et al., 2015a). Location or position cues may take precedence as a memory aid. Alternatively, this preference for corner boxes might derive from a perception that they offer a reduced risk of predation or disturbance (Riber and Nielsen, 2013).

Acceptance of nest boxes can be encouraged by providing perches or raised tiers during the rearing period to allow birds to practice the stepping and hopping movements that may be needed to access nest boxes (Gunnarsson et al., 1999; Colson et al., 2008) and by making nest access as easy as possible in the commercial house e.g. by placing platforms rather than perches just outside the nests (Lentfer et al., 2011; Stämpfli et al., 2013). Strategies for managing birds on first arrival in the house are also essential. Allowing birds to inspect nests before the onset of sexual maturity is also beneficial (Sherwin and Nicol, 1993). When new birds arrive in the house, practices such as confining birds to the slatted areas near the nest boxes, not allowing access to litter substrates, not allowing access to the outdoor range, placing electrified wires on parts of the litter floor where eggs might be laid can inadvertently increase the risk of injurious pecking. Modifying these practices (e.g. to allow newly housed birds access to litter during afternoon periods when most egg laying has finished) can help solve both problems (Lambton et al., 2013).

There have been few studies directly comparing the behaviour of birds in single tier (ST) and multi-tier (MT) systems. One study found lower levels of SFP in MT than ST systems (de Haas et al., 2014a). MT systems provide more perching space but bird movement can also be constrained by the structural features of the system and birds may not access all areas of the house. In free-range units, birds from MT systems may not see or be able easily to access, the popholes, for example.

LH5.4 Behaviour in free-range systems

Range access has benefits in reducing overall stocking density and greatly increased opportunities for birds to perform foraging, exploratory and dust-bathing behaviours. This reduces the risks of injurious pecking. The benefits of outdoor access have to be weighed against risks of disease and predation. Veranda systems may provide better overall welfare than free-range in some environments.

Access to the outdoors allows hens to spread out to preferred distances when foraging, typically greater than 5,000 cm²/hen (Savory et al., 2006), and greatly expands behavioural options, especially if the range offers a variety of plant types (Breitsameter et al., 2014). On good quality range, hens may spend much of their active day engaged in foraging behaviour, searching for, investigating, selecting, extracting, and ingesting preferred food items (e.g., grass seeds, earthworms, and flying insects). They also ingest grit, engage in sun bathing and dust-bathing outdoors and fear levels have been reported to be lower than in barn systems (Ferrante et al., 2009). However, mortality due to predation has been recorded as ranging from 2% (Moberly et al., 2004) to 6% (Defra, 2015; see LH3.2). Many of the benefits of free-range may also accrue in veranda or 'winter garden' systems with potentially lower predation mortality (verandas are often better utilised than the range area (Steenfeldt and Nielsen, 2015a) but there has been little published research on systems (such as the Rondeel™) that provide a veranda instead of a full range area. There is also little information on mortality due to predation under Australian conditions.

Good use of the range significantly reduces the risk of injurious pecking and cannibalism in adult laying hens (Green et al., 2000; Bestman and Wagenaar, 2003; Nicol et al., 2003; Pettersson et al., 2016) and birds that use the range more have improved plumage cover (Rodríguez-Aurrekoetxea and Estevez, 2016). One strategy to increase range use is to limit flock size, as individuals in smaller flocks tend to spend longer on the range (Bestman and Wagenaar, 2003; Gebhardt-Henrich et al., 2014). They may also visit the range more frequently so that an overall higher proportion of the flock is observed on the range area at any one time (Gilani et al., 2014; Steenfeldt and Nielsen 2015a). Range use is also enhanced by lower interior stocking rate (Gilani et al., 2014; Steenfeldt and Nielsen 2015a) and the provision of more (easily accessible) popholes (Gilani et al., 2014). In small experimental trials with individually tagged birds, range use was also increased if outdoor stocking rates were lower. Longer periods of time, and a greater overall time spent outdoors, was achieved at an equivalent stocking rate of 2,000 hens/ha than at equivalent stocking rates of 10,000 or 20,000 hens/ha (Campbell et al., 2017). However, an alternative study found greater range use in birds housed with maximum outdoor stocking rates of >1,000 hens/ha than with <1,000/ha (Sherwin et al., 2013). At very low outdoor stocking rates, birds may be deterred from ranging by a lack of companions. From April 2018, eggs labelled as free-range in Australia must have maximum outdoor stocking rates of no more than 10,000 hens/ha but the effects of outdoor stocking rates on bird welfare would benefit from further study.

Range use in adult birds is enhanced by early exposure to the range during the rearing period (Gilani et al., 2013). Range use is also enhanced by trees, bushes, and artificial cover structures (Nicol et al., 2003; Zeltner and Hirt, 2008b; Gilani et al., 2014) that provide shade and some protection from aerial predators. The perceived threat of aerial predators will lead birds to run back towards the house (Zeltner and Hirt, 2008b). Bright et al. (2011) found a positive correlation between plumage quality and the percent of canopy provided by young trees in planted areas on the range. In a follow-up study of over 1,000 flocks (Bright et al., 2016) the development of the tree canopy was followed as the trees matured. A positive correlation was again noted between plumage quality and the percent of canopy in the planted areas of the range, though there was no relation between plumage quality and the overall area of the range that had been planted with trees, suggesting that the effect was due to improved quality of available cover. In Australian conditions, vertical structures placed on the range were highly attractive to hens and could be used to alter patterns of bird distribution (Rault et al., 2013).

It remains the case that the use of the range by individual birds is highly variable. Gebhardt-Henrich et al. (2014) reported that between 47% and 90% of hens from a sample of 12 flocks (flock size 2,000 – 18,000) visited the range at least once during a 3 week monitoring period. In trials of small experimental flocks Campbell et al. (2017) reported that 2% of birds (from flocks of 150) never used the range, whilst 80% of birds used the range daily when outdoor stocking rate was low, whilst Hartcher et al. (2016a) found that 95% of hens (from groups of 50) accessed the range more than once a day. Rodríguez-Aurrekoetxea and Estevez (2016) found that half of birds in commercial free-range flocks did not use the range at all. Birds with higher fear levels were less likely to spend time on the range (Hartcher et al., 2016a).

LH6. FEAR AND DISTRESS

Measures of stress can often reflect arousal more than the valence dimension of animal welfare and this may explain the many contradictory findings surrounding the stress responses of hens within different housing systems. The nature of the human contact received can greatly affect stress and fear responses in hens.

LH6.1 Stress

It is often thought that early-life stress has particularly profound effects on later life outcomes. In support, a study found that short-term effects of stress (frustrated access to food, physical restraint or a period of social isolation) were more profound if experienced at 2 or 8 weeks than at 17 weeks. But when longer-term outcomes were examined, stress at any of these ages had a significant effect on the birds and it was not possible, overall to identify a specific “sensitive period” when chickens are most stress-susceptible (Ericsson et al., 2016).

A common method used to assess laying hen welfare is to take measures of physiological stress, such as catecholamines, response to ACTH challenge, corticosterone or heterophil:lymphocyte (H:L) ratio. Apart from technical challenges (plasma levels of corticosterone do not necessarily reflect tissue levels (Ralph et al., 2015); handling itself can raise stress levels (Wein et al., 2017), faecal corticosterone metabolite concentrations are affected by genotype and bird diet (Alm et al., 2014), and blood measures such as H:L ratio are not a useful measure if birds are infected with blood-sucking mites (Vezzoli et al., 2016). It should also be recognised that stress responses usually reflect arousal more than they reflect valence. More than one study has found that allowing hens access to highly preferred enriched or outdoor pasture areas is associated with an increase in physiological measures of stress such as H:L ratio (Campo et al., 2013) faecal corticosterone metabolites (Dawkins et al., 2004) or egg corticosterone (Sas et al., 2006). Plasma corticosterone levels can be higher in birds housed in indoor non-cage systems than in caged systems (Pavlik et al., 2008), and faecal corticosterone metabolite levels can also be very high in indoor non-cage systems (Nicol et al., 2006).

Some studies have shown few or no differences between housing systems when physiological markers of stress are considered. Guesdon et al. (2004) and Hetland et al. (2004) found few differences when comparing conventional cages with furnished cages. Barnett et al. (2009) found no differences between hens housed in cages with or without a perch. In this study, even though the perch, and other facilities such as a nest and dust-bath were also used extensively, differences in physiological profile of the birds in each treatment were minimal. Similarly variable or inconclusive results from older studies were reported in Lay et al. (2011).

Many studies have found significantly lower corticosterone levels from hens in furnished cages than hens in conventional cages (Pohle and Cheng, 2009b; Sherwin et al., 2010). Other longer-term markers of reduced stress response, such as lower H:L ratio (Scholz et al., 2008a; Shini et al., 2008; Matur et al., 2015; Dikmen et al., 2016), and higher serotonin levels (Pohle and Cheng, 2009a) are also found in hens from colony cages compared with hens from conventional cages. However, Moe et al. (2010) found higher H:L ratios in hens in FCs compared with CCs.

Experimental studies of brown hybrids kept in floor pens have found lower corticosterone (approx. 31 vs approx. 35 pg/mL) and H:L ratios (0.36 vs 0.52) at stocking rates of 5, 6 and 7 birds/m² than at 10 birds/m² (Kang et al., 2016).

Threshold effects must also be considered. In a study of 36 non-cage ST flocks, Nicol et al. (2006) reported greatly elevated indices of physiological stress towards the end of lay in all stocking rate and management treatments in comparison with levels recorded at the end of the rearing period. For example, H:L ratios had increased from an average of 0.55 to an extremely high value of 1.67; whilst faecal corticosterone metabolite concentrations had doubled from 28.2 ng/g dry matter to 55.2 ng/g dry matter.

LH6.2 Fear

Fear levels assessed by tonic immobility duration were greater in birds housed under a 23L:1D (23 hours light:1 hour dark) photoperiod than in birds allowed longer dark periods for resting (Campo and Davila, 2002) and when birds were housed on damp rather than dry litter (Campo et al., 2009). Fearfulness is reduced in laying hens if they are housed with a proportion (1 per 100) of males (Oden et al., 2005).

Hens housed in conventional cages showed elevated signs of fear in novel object and novel environment tests in comparison with hens housed in aviaries (Colson et al., 2006). As reviewed above, fearfulness is strongly correlated with, and may be a causal factor for, IP. It reduces the time that birds spend on the range (Hartcher et al., 2016a).

Hens in large commercial facilities tend to be fearful of human contact (Graml et al., 2008), although fearfulness can potentially be reduced through appropriate habituation (e.g. regular, close visual contact with a non-threatening human in cage facilities (Edwards et al., 2013). Habituation to humans has also been shown to have productivity as well as welfare benefits (Barnett et al., 1994; Edwards et al., 2010). There is no clear relationship between housing system and fearfulness. Researchers have reported diverse results (e.g. Shimmura et al., 2010b) suggesting that factors within systems, such as the nature and type of human contact received, have a greater effect than housing type itself. Given that

each human has the potential to induce fear in the large numbers of birds that they are responsible for, and that currently humans must interact with birds in a range of ways that is not always predictable to the birds, there is relatively little research in this area. In particular the impact of fear of humans and stockmanship on birds during different life stages has been little studied.

LH7. SENSORY ENVIRONMENT

Hens have sensitive visual, auditory and olfactory senses and a thermoneutral (comfort) zone at an ambient temperature of around 20-25 °C. Extremes (e.g. of photoperiod, light intensity, noise levels, ammonia concentrations and temperature) should be avoided to protect hen welfare. New energy efficient light sources are being used in laying hen housing with limited research so far on their costs or benefits compared with more traditional sources.

LH7.1 Light and vision

The extent to which birds will experience discomfort depends upon their sensory systems. Hens have a highly developed sense of vision. Their spectral sensitivity is slightly greater than humans in both red and blue wavelengths and there is some evidence that UV light may be important for social recognition of individuals. Their spatial acuity – i.e. their ability to detect image detail – is worse than humans and this falls off more rapidly in low levels of light.

Hens may perceive the flicker of some forms of artificial light, which could be detrimental to their welfare (Lisney et al., 2012). Perception depends on the spectrum and brightness of the light source as well as its frequency. The critical flicker fusion frequency (CFF) is the lowest frequency at which a flickering light source is seen as continuous, and it can be estimated for hens using electroretinograms (100-118 Hz: Lisney et al., 2012), discrimination tasks (71.5 Hz: Jarvis et al., 2002; 87-100 Hz: Lisney et al., 2011), conditional reward response (70-105 Hz: Nuboer et al., 1992) and both simultaneous and conditional presentation methods (68-95 Hz: Railton et al., 2009). Behavioural methods estimate slightly lower CFF thresholds than physiological methods, suggesting that central brain processing mediates the signal produced by the eye. Since detection of flicker depends on the spectrum and brightness of the light source used, as well as individual characteristics of different birds, there is no one absolute value for chicken CFF. However, under most conditions, most chickens do not perceive flicker above 95 Hz. This suggests that, contrary to earlier worries, chickens are probably not aware of the flicker of artificial lighting in commercial housing. However, the potential for chickens to discern flicker should be considered where novel light sources are employed.

Light source can influence hen behaviour with, for example, incandescent lights increasing the occurrence of nesting and active behaviours compared with fluorescent lights (Tavares et al., 2015). Coloured LEDs (light-emitting diodes) are increasingly being used to illuminate laying hen facilities due to their energy efficiency and low maintenance requirements (Min et al., 2012). A long-term 15 month study on white hybrids found no significant differences in the mortality of aviary hens housed under LED compared with fluorescent lights. However, some potentially negative effects were noted including poorer plumage quality, reduced food conversion and slightly elevated avoidance responses at 36 weeks but not at 60 weeks of age (Long et al., 2016). Huber-Eicher et al. (2013) compared the behaviour of 16-week pullets kept in pens illuminated (to equal perceived intensities) with white, red (640 nm) or green (520 nm) light. The red light accelerated sexual development, enhanced early laying performance, and reduced aggressive pecking. Birds under green light spent less time directly feeding but more time foraging, pecking at objects and pecking at companions than birds housed under red light. In contrast, Sultana et al. (2013) found that hens were more active under red LED light, showing more FP, ground pecking and scratching and comfort activities and less perching than hens under blue light.

Young pullets prefer high light intensities (200 lux) but older birds prefer lower intensities (6 lux rather than 20, 60 or 200 lux) (Davis et al., 1999). In a continuous-access preference test where hens were able to select compartments illuminated with fluorescent light at <1, 5, 15, 30 or 100 lux, they spent on average 45% of each 24 h period at 5 lux, 22% at 15 lux, 22% at 30 lux, and only 10% at 100 lux. They also spent 10 h in darkness, in intermittent bouts distributed throughout the day, a pattern very different from the continuous dark period that would be experienced under natural or commercial conditions (Ma, H. et al., 2016). Young chicks are also able to rest more when reared under a lighting pattern that simulates natural brooding, with short (approx. 40 min) periods of dark interspersed throughout a long light period compared with an uninterrupted long light period (Malleau et al., 2007). Hens tend to do more pecking under high intensity light (Vandenberg and Widowski, 2000; O'Connor et al., 2011). The diminishing preference of older birds for bright light may cause problems in free-range systems. Where hens are to be exposed to natural light as layers it is important that they experience it during rear. Rearing birds with natural daylight stimulates the earlier development of perching behaviour in young pullets, and results in a stronger diurnal rhythm with more night-time perching and less daytime perching than for birds reared with artificial light of the same photoperiod (Gunnarsson et al., 2008).

Commercial housing systems for laying hens are often kept at low light intensity with the intention of reducing the incidence of feather pecking. However, this method of control can have adverse effects on eye anatomy and function and can be counterproductive in making other foraging substrates appear less attractive than feathers (Bright, 2007). Light intensities as low as 5 lux do not appear to affect the ability of hens to judge distances and jump from perch to perch

(Moinard et al., 2004a) and do not affect stress levels in hens during the early laying period (O'Connor et al., 2011) but at light intensities of just 0.8 lux hen movement is impaired and restricted (Taylor et al., 2003). In addition, social evaluations are partially disrupted at 1 lux but not at 5 lux or above (Kristensen et al., 2009). Dim light, very short or long photoperiods, and continuous illumination, all adversely affect the development of the eye, and its ability to focus (Lewis and Gous, 2009).

LH7.2 Sound, noise and hearing

Research on hearing in chickens is limited but has established their sensitivity to sound; responses varying according to frequency and pressure level but their threshold of detecting sound is at approximately 20-30 dB. Chickens can hear lower frequency sounds than humans and may use them in communications between a hen and her chicks, which are usually below 800 Hz. The important aspect of hearing to note regarding housing design is the growing evidence of not only dislike of but also reduced productivity at loud sounds at levels which are commonly found in fan-ventilated houses. Chronic exposure to 80 dB(A) compared with 60 dB(A) (A-weighted decibels are weighted for loudness as perceived by the human ear) in young laying hens led to more resting behaviour, and reduced egg production (O'Connor et al., 2011). Higher sound levels of 80 dB or 90 dB increase stress (Campo et al., 2005), are a risk factor for the early onset of feather pecking (Drake et al., 2010) and chronic exposure can damage birds' ears. A potential advantage of free-range systems is that birds can avoid excessive noise levels for part of the day.

LH7.3 Olfaction

Chickens have well-developed senses of smell and of taste (gustation) and a trigeminal-nerve induced rapid protective responses to harmful or irritating chemical stimuli. The chicken genome contains at least 229 genes coding for olfactory receptors, but far fewer coding for genes related to human bitter or sweet taste receptors (Lagerstrom et al., 2006).

Chicks develop attachments to familiar odours when placed in an otherwise novel environment (Jones et al., 2002). Domestic fowl of a traditional breed increased their vigilance behaviour after exposure to the odour of a predator than after exposure to odour cues from herbivorous mammals (Zidar and Lovlie, 2012).

Exposure to ammonia may reduce poultry welfare by causing irritation to mucous membranes in the eyes and respiratory system, increasing susceptibility to respiratory disease and reducing productivity (Kristensen and Wathes, 2000). Preference tests with broiler chickens show that exposure to ammonia concentrations above approximately 10 ppm is aversive, regardless of previous experience (Jones et al., 2005), whilst laying hens show signs of avoiding concentrations of 25 ppm (with lower concentrations not tested) (Kristensen et al., 2000). On free-range farms with an average ammonia concentration of 22 ppm, an earlier onset of feather damage due to injurious pecking occurred on those farms with the higher ammonia levels (Drake et al., 2010). An ammonia concentration of less than 25 ppm is a realistic target (and a threshold set for human exposure in many countries), but as described above this may be difficult to achieve in highly stocked indoor houses. Many viral, bacterial, fungal and parasitic diseases organisms rely on aerial transmission to other birds and humans. Reducing this disease risk can be achieved by regular short periods of high ventilation rates and possibly by also offering birds a choice of an outdoor/veranda environment with fresher air.

LH7.4 Magnetic sense

Laying hens are able to use the Earth's magnetic field orientation (Freire et al., 2005; Zimmerman et al., 2009), which may have implications for their ability to orient and navigate in non-cage systems. The presence of magnetoreceptors in the beak suggests that their magnetic sense may be disrupted by beak-trimming (see LH8.3b).

LH7.5 Thermal comfort

The thermal requirements of hens and their housing are long established. Essentially their heat output follows a cup-shaped curve with increasing temperature. This has a so-called thermoneutral zone, usually around 20-25 °C, where the bird is very comfortable and does not need to expend any effort in keeping comfortably warm. Below this zone the feed requirement and metabolic effort required to keep warm increases with decreasing temperature until the bird experiences cold stress and has to shiver. It will eat more to keep warm, may produce fewer eggs and signs of physiological stress such as increased H:L ratio are seen if temperatures drop below 10 °C (Campo et al., 2008). Above the thermoneutral zone the bird needs to work to keep cool, eventually panting, which requires extra water consumption; additionally the bird will eat less and produce smaller eggs in very hot conditions. In both cases a wet or humid environment increases cold or heat stress. Such variations in temperature and humidity are a disadvantage of free-range systems, where the requirement for continuous daytime access means that pop-holes are open to the elements. Thermal stress is influenced by bird weight, fat cover, feather cover and by air movement (i.e. draughts and wind), radiation (e.g. sunlight) and conduction (in practical terms dictated by floor type/insulation and whether birds are touching each other). Birds may adjust their own body temperature by behavioural thermoregulation – i.e. by altering their posture, in particular spreading out their wings and standing when hot and huddling together when cold – and by seeking out a warmer or cooler place in their environment, which should provide the choice and freedom to move. Mortality can be increased in conventional cages which prevent birds adopting these postures (Guesdon and Faure, 2004; Guo et al., 2012). A study of the effects of

increasing space allowance per bird from 348 cm²/hen to 581 cm²/hen in an existing conventional cage facility concluded that the reduced flock size would result in a reduction in overall heat and moisture generated within houses. In cold weather this could have some disadvantages in maintaining a suitable temperature for the birds without compromising air quality, but it was considered to be advantageous to avoid heat stress during hot weather (Green and Xin, 2009a). However, under conditions of intense heat (above 32 °C), increased space allowances of 581 cm²/bird assist but do not fully enable birds to cope with heat stress (Green and Xin 2009b). The provision of cooled perches can enable birds in CCs to cope better with temperatures between 32 to 35 °C (Hu et al., 2016). There is no simple relation between cage type (CC vs FC) and the ability of birds to cope with heat stress as the benefits of increased space per bird can be counteracted by increased activity in cages with larger numbers of birds (Shimmura et al., 2007b). Within FC systems, hens in smaller group sizes of 25 appear to cope better with high temperatures, and maintain higher production, because they are less active than birds in larger groups (40) (Bovera et al., 2014).

LH8. HANDLING AND MANAGEMENT

LH8.1 Stocking density and group size

In caged environments space allowances of less than approx. 600 cm²/bird are associated with increased mortality, an increase in physiological stress and compromised immune function. In non-cage systems the effects of stocking rates between 7 and 12 birds/m² are inconsistent, possibly because uneven bird distribution can be a confounding factor.

Some of the effects of stocking rate on bird behaviour in CCs were reviewed above in LH5.1. For hens kept in CCs, mortality increased if hens were housed at 375 cm²/bird or 450 cm²/bird compared with 563 cm²/bird (Rech et al., 2010).

Increased liver pathophysiology and renal damage has been reported for birds housed in CCs at 351 cm²/bird compared with 526 cm²/bird (Ma Z. et al., 2014; Ma Z. et al., 2016b) and lower individual bird production is seen if birds are housed at 362 cm²/bird compared with 482 cm²/bird (Anderson et al., 2004), or at 342 or 413 cm²/bird compared with 516 cm²/bird (Jalal et al., 2006), with further enhanced individual production by birds housed at 690 cm²/bird (Jalal et al., 2006). In hens kept on for a second laying period, feed efficiency was improved with space allowance increased from 309 cm²/bird to 412 cm²/bird (Sohail et al., 2004). Higher H:L ratios were reported for birds housed at extremely low spatial allowances, 288 cm²/bird, compared with 500 cm²/bird (Cetin et al., 2011) but no differences in H:L ratio or adrenal gland weight were reported for birds housed in conventional cages at 542 cm²/bird (4 birds/cage) or 434 cm²/bird (10 birds/cage) (Fahey and Cheng, 2008a) or for plasma corticosterone or H:L ratio for hens housed at 320 cm²/bird (5 birds/cage), 400 cm²/bird (4 birds/cage) or 533 cm²/bird (3 birds/cage) (Mousavi et al., 2016). This may be because the differences in spatial allowance in these studies are marginal. In experiments that have compared a wider range of space allowances within CC systems, clearer differences have been found. Hens were housed at 1,968 cm²/bird (1 bird/cage), 656 cm²/bird (3 birds/cage) or 384 cm²/bird (5 birds/cage). Groups housed at the highest stocking rate had lower body weight, production, plumage score and higher H:L ratios, whilst the individually-housed birds with the largest space allowance had lower plasma corticosterone levels (Onbaşlar and Aksoy, 2005). Similarly, when hens were housed at 2,000 (1 bird/cage), 1,000 (2 birds/cage), 667 (3 birds/cage) or 500 cm²/bird (4 birds/cage) mortality due to IP was lower and plumage condition was better at the two higher spatial allowances (Sarica et al., 2008). Individual bird production was also improved at this higher spatial allowance (Saki et al., 2012).

Increased stocking rate was associated with increased H:L ratio, but not in markers of cell mediated immune function in laying strain chicks reared in cages at 212, 275 and 371 cm²/bird (Bozkurt et al., 2008).

A possible effect of increasing group size within FC systems is on bird mortality, with higher mortality in systems with 20 to 60 birds, than FCs for 10 birds (Weitzenburger et al., 2005a). There was more locomotion in large furnished cages with greater group size than in small furnished cages with smaller groups (Weitzenburger et al., 2006a; Meng et al., 2017) and more wounds and reduced plumage condition in FCs with 16 birds than those with 8 birds (Hetland et al., 2004). Appleby et al. (2002) reported increased mortality in furnished cages with 8 birds than those with 4 birds. In contrast, no significant differences in mortality were reported for increases in group size from 8 to 40 by Wall (2011) or from 20 to 60 by Huneau-Salaun et al. (2011b).

In a small study that controlled for group size, Barnett et al. (2009) found decreased plasma corticosterone in hens housed in furnished cages at a space allowance (including cage furniture) of approx. 1,800 cm²/bird compared with a space allowance of approximately 900 cm²/bird. In another study that controlled for group size, Kang et al. (2016) found improved production performance and reduced stress response (see Section LH6.1 above) in hens housed in floor pens at less than 10 birds/m² compared with birds housed at 10 birds/m².

Higher stocking rate for pullets during the rearing period is associated with increased feather damage due to pecking (Bestman et al., 2009). Rearing flocks where feather pecking was identified had been stocked at between 18 and 53 chicks/m² between weeks 1 and 4, whilst rearing flocks with no feather pecking had been stocked at between 15 and 37 chicks/m² (Bestman et al., 2009).

The effects of stocking rate on the physical condition and pecking behaviour of non-cage flocks are complex. In a relatively small scale experimental study, FP was found to increase with stocking rate from 6 to 30 birds/m² (Nicol et al., 1999) but subsequent work with large commercial flocks found an opposite effect with stocking rates from 7 to 12 birds/m² (Zimmerman et al., 2006). An analysis of the physical condition of birds from these same flocks found lower mortality at 12 birds/m² than at 7 or 9 birds/m² (Nicol et al., 2006). The reason for this difference is not clear but Nicol et al. (2006) noted that there can be paradoxical effects in large commercial flocks if birds at lower average stocking rates cluster rather than disperse evenly.

In a study of organic flocks it was this increased resource competition that was thought to be responsible for greater plumage damage in birds kept in aviary systems at higher stocking rates within the range of 6 to 12 birds/m² (Steenfeldt and Nielsen, 2015b). Other effects of increasing stocking rate in these flocks were felt to be minor (Steenfeldt and Nielsen, 2015a).

It should be recognised that birds do not distribute themselves evenly (LH4.5), either in FCs or in non-cage systems (LH5.3). Tendencies to cluster can arise for many reasons including social facilitation, shared resource preferences, and anti-predator responses (LH4.5). In experimental pens housing groups of between 323 and 912 birds, each at a notional stocking rate of 18.5 birds/m², the local densities recorded in different pen areas varied between 9 and 41 birds/m² (Channing et al., 2001).

LH8.2 Air quality and biosecurity

Air quality (dust, bacteria and ammonia levels) is lower for non-cage systems containing litter than for cage systems or multi-tier systems with belt removal of manure.

Reduced air quality for non-cage systems containing litter compared with colony cages or multi-tier systems with belt removal of manure has been noted in many studies, with more inhalable and respirable dust particles, bacteria and associated endotoxins present in the air (Rodenburg et al., 2008a; Nimmermark et al., 2009; Huneau-Salaun et al., 2011a; Le Bouquin et al., 2013). Nimmermark et al. (2009) reported total dust concentrations of up to 2.5 mg/m³ in FC and non-cage MT systems, but up to 18 mg/m³ in a litter floor ST house. Ammonia concentrations varied from 3-12 ppm in FC, 21-42 ppm in the MT system and 66-120 ppm in the ST house. Under winter conditions in Iowa, USA, ammonia concentrations were adequately maintained below 25 ppm in two cage facilities, but not in a non-cage facility where ammonia rose to a maximum of 89 ppm (Green et al., 2009). However, under summer conditions, the ammonia concentrations were equally low for all three systems. In practice there is often a trade-off between keeping rates of ventilation low in winter in order to maintain warmer air temperatures for efficient feed conversion and production as well as bird comfort; and in maintaining good air quality. Maintaining air quality throughout the year can also be a challenge in very large conventional cage facilities with high house stocking density. Chai et al. (2010) reported mean ammonia concentrations varying across a large commercial cage facility from 7.1 to 47.7 ppm, whilst carbon dioxide varied from 2,302 to 3,452 ppm. Ventilation rates of just over 2.0 m³/h/hen have been reported in large commercial facilities housing 250,000 birds, though fan performance was highly variable and subject to degradation with time (Chai et al., 2012).

Each system varies with respect to the risk of infectious disease outbreaks. Good biosecurity is essential in all cases. Systems with outdoor access will be more vulnerable to infection from free-ranging birds and all systems are likely to be at risk from fomites transferred on people, equipment or food. The nature and persistence in the environment of the infectious agent will influence the risk to birds in different systems. Avian Influenza may be passed directly between birds and can survive in the environment for at least 50 days in cool conditions (Defra, 2016).

LH8.3 Procedures

LH8.3a Culling Male Chicks

Research work is ongoing to find a cost-effective methodology to screen and remove male embryos before hatching.

Since only female chicks are reared for egg production, billions of unwanted male chicks are culled each year globally, a practice that raises ethical and practical concerns. Currently male chicks are commonly culled using carbon dioxide gas or by instantaneous mechanical destruction (maceration) (welfare implications reviewed in SL2.7a and SL2.7b).

Accurate methods of *in ovo* sexing are now available and would avoid the need for culling. For example, the cellular DNA in male and female chicks differs and can be detected within seconds *in ovo* by Fourier transform infra-red spectroscopy (Steiner et al., 2011). Alternatively, endocrine *in ovo* sexing can be achieved by sampling allantoic fluid. Such methods do not appear to have any adverse effects on later development and welfare of the female birds (Weissman et al., 2014). Gene editing is another approach that is being explored whereby male embryos could be engineered to carry a gene making them identifiable before hatch (Doran et al., 2016). These techniques, still realistically in a development phase, have not been implemented commercially but, in a high-profile announcement in 2016, USA United Egg Producers stated their intention to eliminate the culling of male chicks by 2020 (<http://uepcertified.com/united-egg-producers-statement-eliminating-male-chick-culling/>).

LH8.3b Beak Trimming

Beak trimming is an effective method of reducing the damage caused by injurious pecking. The procedure causes pain and reduces beak function. Beak trimming day-old chicks at the hatchery using an infra-red method appears to be less painful and cause fewer long-term negative effects than hot-blade trimming. However, research on pain associated with infra-red trimming is still limited. An alternative approach is to provide birds with pecking blocks whereby the beak is gradually blunted over a prolonged period of time. Further research on beak blunting is needed.

Beak trimming conducted either by infra-red (IR) or hot blade (HB) (Dennis et al., 2009) is a management practice adopted to reduce the damage caused if birds peck each other. The practice can significantly reduce mortality in conventional and furnished cages (Guesdon et al., 2006) and in non-cage flocks (Mertens et al., 2009; Defra, 2015; Weeks et al., 2016). Weeks et al. (2016) conducted a quantitative analysis of mortality data from 801 beak-trimmed and 228 intact-beak flocks housed between 2006 and 2012 and found significantly (but not dramatically) lower mortality in the beak-trimmed flocks at 40 weeks and at 70 weeks (7.2% vs 8.3%), using a model that accounted for many other bird and management variables. Flocks of adult beak-trimmed birds have improved plumage condition compared with intact-beak flocks (Staack et al., 2007; Lambton et al., 2010; 2013; Sepeur et al., 2015). The effects can sometimes be substantial, with Hartcher et al. (2015a) in a study of free-range flocks, recording just 5.2% of beak trimmed, but 72.9% of birds with intact beaks, with feather damage or wounds. This is largely because beak-trimmed birds perform less severe feather pecking (though more gentle feather pecking) (Gilani et al., 2013; Lambton et al., 2013; Hartcher et al., 2015a).

The effects of beak-trimming on younger birds are less clear and can sometimes lead to increased plumage damage (Staack et al., 2007). Re-trimming the beaks of older birds is sometimes applied as an emergency measure if outbreaks of injurious pecking have become severe. It can be effective (Shimura et al. 2006b) but trimming at an older age is thought to cause more stress and pain than early beak trimming (Janczak and Riber, 2015).

Beak trimming is a welfare concern because it can cause pain and changes in function (Freire et al., 2008; Freire et al., 2011). HB trimming is accompanied by reduced growth rate, feed intake (Prescott and Bonser, 2004), pecking force and activity (Janczak and Riber, 2015). It also increases adrenocorticotrophic hormone levels in the blood and altered immune function (Xie et al., 2013). The fact that the administration of analgesic drugs partially ameliorates these responses is suggestive that the procedure is perceived as painful (Freire et al., 2008). No signs of chronic pain are observed if HB trimming is conducted on very young birds and where only a small portion of beak tissue is removed (Freire et al., 2011). But the accuracy of the method is not high and it is difficult to standardise. There is, for example, no clear relationship between chick weight and beak characteristics that could be used as a guide (Fahey et al., 2007). If a large portion of the beak is removed nerve swellings (neuromas) can form and these may continue to send pain signals to the brain even in adult birds (Janczak and Riber, 2015). Recent work shows that healing is faster if HB trimming is conducted at 0 or 10 days than at 35 days of age (Schwean-Lardner et al., 2016).

Beak trimmed birds, for example, show compromised preening activity and can have higher ectoparasite loads as a result (Mullens et al., 2010; Vezzoli et al., 2015b). Chen et al. (2011) documented changes in populations of the northern fowl mite and the chicken body louse in both intact-beak and (hot blade) beak-trimmed birds. At peak periods of infestation, beak-trimmed birds harboured between 4.6 and 7.8 times more lice, and between 5 and 40 times more mites, than intact-beak birds. Increased beak sensitivity (to heat and pressure) is also observed in birds that have been HB beak-trimmed at hatch or at 14 weeks, although in this experiment the overall number of pecks made at feed and the environment did not differ from untrimmed controls (Jongman et al., 2008). In addition, significant changes in navigational ability and functional activity are detected due to damage to mechanoreceptors and magnetoreceptors in the beak (Freire et al., 2011).

IR trimming has been proposed as a more precise (Carruthers et al., 2012), less harmful and less chronically painful method than HB (Dennis et al., 2009; McKeegan and Philbey, 2012). Chronic effects on bird welfare are more likely in birds that are HB trimmed at the age of one week or older. One of the advantages of IR trimming is that it is now a highly automated process that is routinely conducted at hatcheries on birds that are less than 2 days of age, and possibly less likely to develop long-term effects at this age (Janczak and Riber, 2015). During the hatchery procedure, chicks are restrained by their heads, whilst calibrated machinery is used to expose a specified area of beak tissue to infra-red energy. The exposed outer corneum remains intact but the treated beak tip is shed some days after treatment, and regrowth is inhibited due to the extensive penetration of heat to the germ layers.

Hens that had received IR trimming at hatch had shorter, less variable beaks, with fewer abnormalities as adults than hens that had been HB trimmed (Carruthers et al., 2012). McKeegan and Philbey (2012) found no evidence of nerve sensitisation (using single sensory nerve recording), no radiographic evidence of adverse pathology, and, in older birds, no signs of neuroma formation. Birds that have been IR trimmed are also more able than HB trimmed birds to control mite infestations through preening behaviour (Murillo and Mullens, 2016). However, IR trimming does have some adverse effects on birds' behaviour and development. Normal ground pecking was suppressed alongside feather pecking in birds subjected to an early IR treatment followed by a later HB treatment (Hartcher et al., 2015a). Dennis and Cheng (2012) found walking, drinking and pecking behaviour less disturbed in young birds subjected to IR than birds trimmed using the HB method. But birds trimmed using either method show drops in normal feeding behaviour in the first weeks of life (Marchant-Forde et al., 2008) and reduced weight gain (Angevaere et al., 2012).

An alternative approach is to provide birds with hard materials that are attractive pecking substrates. Pecking blocks of a variety of designs and materials are now available (e.g. Vencomatic pecking pans). As the birds engage in normal exploratory pecking, the tips of their beaks are blunted, thereby reducing the damage that birds may inflict if they feather peck. There have been a few small-scale studies of the effectiveness of beak blunting but evidence from peer-reviewed replicated studies is currently lacking. Another potential future approach would be the genetic selection of birds with naturally blunter beaks.

Organic certification bodies prohibit the use of routine beak trimming, and a number of EU member states are currently considering whether the practice of beak-trimming should be banned completely. Furthermore, in some EU countries such as Austria, there is an increasing demand for eggs from hens with intact beaks.

LH8.3c Moulting

Laying hens have a tendency to become less productive with time, particularly when housed in cages with limited opportunities for exercise. Productivity can be restored to some extent by an extended period of total or partial withdrawal of food which induces a forced moult. This practice is associated with greatly increased mortality during the feed withdrawal period. There is strong evidence that the procedure causes stress and that the birds are highly motivated to eat. The provision of low nutrient diets during the moulting procedure does not appear to reduce hunger. This practice has strongly negative welfare consequences. The emergence of strains of birds selected for longer laying cycles reduces the need to engage in this practice.

The practice of moulting laying hens has traditionally involved a period of total food withdrawal from hens for a period of approximately 10 to 14 days, followed by a similar duration of time where a low nutrient diet is fed so that an overall moulting period has a duration of approximately 28 days. In some countries water is also withdrawn for a period of up to 3 days (Shimmura et al., 2008b). Withdrawal of water would have severe negative consequences for hens, which show behavioural changes indicative of thirst after periods of 12-18 h (Rault et al., 2016).

The practice is sometimes justified on the basis that many birds undergo an annual moult, with bodyweight loss and a pause in oviposition (Mrosovsky and Sherry, 1980). However, the many factors that bring about a natural moult (including changes in environmental temperature and photoperiod) do not operate in commercial conditions where birds are abruptly deprived of food at a time when they are still motivated to eat.

The practice of moulting is banned in the EU under Council Directive 98/58/EC which stipulates in paragraphs 14 and 15 of the Annex that “animals must be fed a wholesome diet which is appropriate to their age and species and which is fed to them in sufficient quantity to maintain them in good health and satisfy their nutritional needs” and that “all animals must have access to feed at intervals appropriate to their physiological needs”. For this reason there are no recent European studies available on this practice.

In the USA, following a decision by some retailers not to accept eggs from hens that had been moulted, United Egg Producers initiated a research programme on alternative methods of achieving a moult without total feed withdrawal. Thus, in the USA, there have been a number of research programmes evaluating the effects of feeding low nutrient diets. More sporadic research has also been conducted in other countries including Japan, Turkey, Iran, Colombia, Thailand and Brazil. Low nutrient diets are diverse and can be formulated from a variety of ingredients such as wheat “middlings” (Biggs et al., 2003), low nutrient corn diets or fruit pomace (skins of fruit after pressing) (Keshavarz and Quimby, 2002), soybean hulls (Koelkebeck and Anderson, 2007), alfalfa (Donalson et al., 2005; Sgavioli et al., 2011; 2013), distillers’ grains (Mejia et al., 2010), other low-nutrient diets with low levels of calcium, sodium and protein (Bell and Kuney, 2004), high zinc diets (Park et al., 2004; Silva-Mendonca et al., 2015) or diets containing plant extracts that suppress appetite or contain anti-nutrient factors (Mohammadi and Sadeghi, 2009; Sariozkan et al., 2013). The total moulting period is again usually around 28 days.

Alternative strategies are to feed very low quantities of feed rather than total withdrawal (Molino et al., 2009), to mimic changes in daylength and in physiological levels of the hormone thyroxine, which is implicated in the natural moulting process of some birds (Kuenzel et al., 2005; Bass et al., 2007), or to feed an orally active progestin, melengestrol acetate (MGA) to induce moult without feed deprivation (Koch et al., 2007).

Mortality can be high during the moulting period, whether the birds are deprived of feed or whether feed substitution methods are used (average 2.1% in 4 weeks (Keshavarz and Quimby, 2002); 2.7% in 4 weeks (Biggs et al., 2003); average approx. 2.5% in 4 weeks, up to 6.1% on some farms (Bell and Kuney, 2004); 1.9 to 2.3% (Anderson and Havenstein, 2007); average 3.9% in 6 weeks (Yardimci and Bayram, 2008); 10.4% in food or food and water withdrawal treatments (Shimmura et al., 2008b); 0% for some dietary treatments but up to 5.5% in 4 weeks for hens fed distillers’ grains (Mejia et al., 2010); 4.4% in 1 week (Rafeeq et al., 2013). Actual mortality levels are not presented in some studies which instead simply indicate no significant differences in mortality between treatments (Park et al., 2004; Donalson et al., 2005; Willis et al., 2008; Mazzuco et al., 2011; Mejia et al., 2010; 2011; Bland et al., 2014).

Birds that do not die experience substantial weight loss. For hens deprived of feed for 10-14 days figures of 19.7% (Biggs et al., 2003), 20.1 to 25.1% (Bell and Kuney, 2004), 30% (Shimmura et al., 2008b), 30.2% (Keshavarz and Quimby, 2002),

37% (Rafeeq et al., 2013), or 30 to 42.3% (Willis et al., 2008) have been recorded. Weight loss occurs due to decreased muscle, liver and adipose tissue as well as regression of reproductive tissue (Park et al., 2004). In addition, in caged birds already subject to challenges of disuse osteoporosis (see Section LH3.4), bone mineral density and content are significantly reduced (by up to 39%) (Mazzuco and Hester, 2005; Kim et al., 2006; Mazzuco et al., 2011; Ayasi et al., 2016), though levels may eventually recover by 126 days post-moult (Mazzuco and Hester, 2005).

Hens fed alternative moulting diets still lose weight (16.2 to 30.3% over 28 days (Keshavarz and Quimby, 2002); 15% over 28 days, (Biggs et al., 2003); 11.8-23.4% over 14 days (Bell and Kuney 2004); 21-29% over 10 days (Sariozkan et al., 2013), 26-27% over 7-8 days (dos Santos et al., 2014). If alternative moulting diets (for example those containing distillers' grain formulations) do not produce such substantial weight loss then the entire procedure can be ineffective in causing regression of ovarian and oviduct tissue, cessation of egg-laying and a return to higher post-moult productivity (Mejia et al., 2011; 2014; Bland et al., 2014). The same tension is seen if periods of total food deprivation are reduced to around 6 days: bodyweight loss is reduced (Bell and Kuney, 2004), but the effectiveness of the moult in terms of future production gains is also reduced. However, by feeding dietary thyroxine, egg production can be halted but with reduced mortality (0.8%) and bodyweight loss (14-16%) (Bass et al., 2007).

During food withdrawal, indices of fearfulness increase (Altan et al., 2005) with increases in plasma corticosterone during the initial 48 h of feed deprivation (Webster, 2003). Antioxidant status is compromised (Mert and Yildirim, 2016). Increases in H:L ratio (Altan et al., 2005; Dunkley et al., 2007) and acute phase protein markers of inflammation are sometimes observed between days 9 and 12 (Dunkley et al., 2007). However, whether or not an increase in H:L ratio is observed appears to be highly variable between studies. For example Soe et al. (2009) recorded a baseline H:L ratio of 8.4 in control birds, which was elevated to between 25.3 to 35.0 by day 10 in hens fed a low nutrient diet. By day 25, H:L ratios had recovered for most groups but remained elevated for hens that had been fed the low nutrient diet for 4 weeks. Aygun and Yetisir (2009) reported baseline H:L ratios of 0.34 which had increased to between 0.60 and 0.67 by the end of a 42 day moulting period. Ayasi et al. (2016) reported a significantly elevated H:L ratio on day 6 (0.13 controls, 0.27 food withdrawal) and day 9 (0.10 controls, 0.20 food withdrawal) but non-significant changes in birds on non-nutritive alternatives to food withdrawal. Dickey et al. (2010) and Gongruttananun et al. (2013) reported no increases in H:L ratio. From a public health viewpoint it has become a matter of concern that food deprived birds become more susceptible to infection e.g. from *Salmonella enteritidis* (Woodward et al., 2005). Some studies have evaluated feedstuffs with anti-microbial properties to try to mitigate this effect (Willis et al., 2008).

Large increases in activity (Webster, 2003; Dickey et al., 2010) and non-nutritive pecking (Dunkley et al., 2008a; 2008b; Mazzuco et al., 2011; but not Dickey et al., 2010) are observed before birds become relatively inactive to conserve energy, primarily using their lipid reserves. Increases in aggression (Webster, 2003) and injurious pecking have also been noted (Anderson et al., 2004). A study into the question of how hunger is experienced by birds during moult was conducted by Koch et al. (2007). These authors directly evaluated the birds' feeding motivation using a progressive ratio pecking task, where number of pecks to obtain a 3 s access to a feed reward increased by 1 after each previous reward. Birds were fasted for a period of 8 days, and by day 8, the fasted birds pecked more than 250 times in a 15 min session to obtain 3 s rewards. Importantly, birds in a nutrient substitution treatment, fed wheat middlings for a period of 20 days showed levels of hunger that approached that of the food deprived birds on day 8, and exceeded those of the food deprived birds by day 20. By day 20 the wheat middling group made an average of approximately 300 pecks in 15 minutes to obtain 3 s rewards of normal food. The conclusion was that feeding low-nutrient diets during moulting does not reduce hunger or improve animal welfare. In contrast, birds induced to moult by feeding the progestin MGA, and provided with normal rations, showed no evidence of increased hunger (Koch et al., 2007).

It should also be noted that post-moult mortality during a second laying phase is substantially higher than during the first laying phase. The moulting procedure actually reduces post-moult mortality in comparison with non-moulted birds kept for a second laying phase but post-moult mortality is high: >10% in a 43 week period (Anderson and Havenstein, 2007), between 15 and 27.5% in a period comprising 4 week moult and 18 week post-moult monitoring (Onbaşilar and Erol, 2007), and up to 25% in a 25-35 week post-moult period (Galeano et al., 2012). Plumage condition does not return to that seen during first early-lay period (LaBrash and Scheideler, 2005).

A water supply is usually readily available to laying hens, except in circumstances such as transportation or (exceptionally) during the forced moulting procedure. After a 12 h period of water deprivation, frequency of drinking was increased, whilst deprivation of more than 12 h resulted in behavioural changes, including spending more time in the vicinity of a drinker. Total duration of drinking increased after deprivation periods of over 18 h (Rault et al., 2016). Despite these signs of thirst, hens did not increase the effort they were willing to expend (by squeezing through a narrow gap) to reach a drinker as water deprivation time increased (Rault et al., 2016) The thermal environment of the bird will obviously affect its water requirements.

Some researchers have argued that low nutrient diets provide a feasible alternative to total fasting. However, it is not clear that these strategies (with their rather variable results) are actually implemented on farms, and the broader scientific evidence suggests they may not improve bird welfare. There is no evidence that alternative methods that induce moult by hormonal manipulation (e.g. MGA) are actually being used in practice. The very problem is partly a consequence of

keeping birds in conventional cages where they cannot exercise and become over-fat. A combination of moving towards FCs or non-cage systems that allow birds to exercise, and the emergence of new strains of laying hens with longer productive first laying cycles (Bain et al., 2016) should see forced moulting become a redundant practice. In the UK many farmers are now depopulating flocks at 80 to 90 weeks, rather than 65-72 weeks as in the recent past.

LH8.3d Comb and wattle trimming

In Europe pullets are not subjected to comb or wattle trimming (“dubbing”). However, in the USA, up to 19 million pullets have their combs trimmed to improve production efficiency, as trimmed birds consume marginally less food. Apart from the likely pain caused by cutting an enervated tissue, comb trimming reduces the ability of hens to thermoregulate during hot weather. During and after a 50 h period at 34.6 °C, comb-trimmed birds showed greater signs of heat stress (panting and wing spreading) and highly significantly increased mortality in comparison with controls (Al Ramamneh et al., 2016).

LH8.3e Cage cleaning

In smaller facilities (e.g. backyard) removing hens from cages for cage cleaning purposes can increase mortality (Anderson et al., 2010).

LH9. REARING

There is growing evidence of the important influence of rearing conditions on the behaviour and welfare of birds in the laying period. Pullets reared with litter and with perches have improved welfare as adults, but more studies are needed particularly in the commercial environment.

Chicks arrive at rearing facilities at “day-old” and will already have experienced many stressors related to handling (for sorting and sexing), vaccination, beak-trimming, transportation and unloading. It is therefore essential that they are provided with a safe, warm and comfortable environment on arrival, with food readily available to avoid problems of “starve-out” (the failure of chicks to find, or accept, food or water, resulting in starvation). There is little scientific information on the welfare of very young chicks, but there is growing evidence that simulating aspects of natural maternal care can have strongly beneficial effects in encouraging chicks to learn about food, in reducing fear, increasing behavioural synchrony, and buffering chick stress response compared with artificially-reared chicks (Riber et al., 2007; Edgar et al., 2013; 2015). Despite this, only a narrow range of outcomes have so far been assessed and the mechanisms underpinning the documented benefits are poorly understood.

Pullets reared in cages have a reported mortality of approximately 7% by 16 weeks of age, though with no differences attributed to stocking rates varying from 212 to 370 cm²/bird (Bozkurt et al., 2006). Pullets reared in FCs have improved immune function compared with pullets reared in CCs (Matur et al., 2016).

Current understanding is that the rearing environment should match the laying environment and provide the pullets with prior experience of conditions they will encounter during lay (Janczak and Riber, 2015). European studies have found that birds reared on the floor or in aviaries had subsequently higher mortality in FCs or similar group-housing systems, than cage-reared birds (Weitzenburger et al., 2005a; Vits et al., 2006; Tahamtani et al., 2014). Hunniford and Widowski (2016) also found that cage-reared hens were more likely to lay within the nestbox area in furnished cages than those reared on litter. It is rare for cage-reared pullets to be reared in furnished cages, and is not a requirement within the EU despite the prohibition of barren cages for layers, yet it would appear important for them to experience perches and scratch areas at the least.

However, results on the value of consistent rearing and laying environments are not universally consistent. One Mexican study (Itza-Ortiz et al., 2016) found that floor-reared white birds moved to conventional cages had lower mortality than cage-reared birds.

The importance of providing litter during the rearing phase was reviewed in section LH3.5. Many studies have reported beneficial effects of providing early access to perches on later behaviour and other outcomes for laying hens, particularly those housed in non-cage systems. Early perch access facilitates the development of muscle strength (Hester et al., 2013), motor skills, and spatial navigational abilities (Gunnarsson et al., 2000a), although in cage systems early access to perches does not increase adult perch usage (Hester et al., 2014). In contrast, in non-cage systems, early perch access increases the ability of hens to reach elevated structures as adults (Gunnarsson et al., 2000; Heikkilä et al., 2006). Studies on birds fitted with accelerometers show that young pullets are most likely to display high-intensity physical activity, whilst in older birds physical activity declines (Kozak et al., 2016a). This demonstrates the importance of providing environments that encourage the development of motor skills and strength in young birds, who will use ramps and other elevated structures from as young as 2 weeks of age (Kozak et al., 2016b). A more complex rearing environment with elevated structures, produces birds that demonstrate greater use of elevated aviary levels, higher accuracy of long flights and jumps, lower pullet mortality, and a higher proportion of eggs laid in nest boxes during adulthood (Colson et al., 2008).

Provision of perches also reduces later problems with feather pecking (Gunnarsson et al., 1999; Huber-Eicher and Audigé, 1999) possibly because birds learn how to avoid trouble-makers by moving in three dimensions.

Dark brooders are a comparatively new technique of providing chicks and pullets with heat during rear. These generally comprise a platform with heating elements underneath it and dark curtain sides enabling young birds the choice of moving into the warm, dark, environment or out to the lit and cooler whole house environment. They are gradually being adopted for use in commercial rearing since a large on-farm study found a reduced prevalence of severe feather-pecking and improved plumage condition in intact birds over the period from brooder placement to 35 weeks of age, with no adverse effect on growth, body-weight uniformity, or mortality to the end of rearing (Gilani et al., 2012). Dark brooders may also improve behavioural synchrony between birds, reduce disturbances during resting, and result in calmer birds (Riber et al., 2007; Gilani et al., 2012).

Two surveys of commercial flocks in the UK have shown that higher levels of background noise during rear increases the risk of feather pecking both in terms of early onset and the extent of damage during rear (Drake et al., 2010; Gilani et al., 2013) thus designing quieter environments during rear should prove beneficial.

When pullets are transferred to non-cage laying facilities they are sometimes excluded from key resources, including the range and the litter area, for a variable period until egg laying in nests is fully established. The impact of such nest box “training” on hen welfare is not clear. Alm et al. (2015) found improved indicators of plumage condition and fearfulness in flocks that were excluded from the litter resource for 2 weeks whereas Lambton et al. (2010) found that this practice led to significantly worse plumage condition at 25 weeks of age.

LH10. BREED EFFECTS

Red Junglefowl perch more than domestic hens, and show a greater degree of social facilitation and synchrony (Eklund and Jensen, 2011).

Hocking et al. (2004) compared behavioural traits in 25 breeds of laying hen (13 traditional and 12 commercial strains). Strong strain differences were found in tendency for IP (and resultant wounds and mortality) but not for fearfulness or for other measures of overall behavioural time budget.

In FCs some studies have found strain differences in perch use (Wall and Tauson, 2007) but these are not consistent between studies. A more comprehensive study directly compared the spatial distribution of 4 strains of laying hen in a multi-tier aviary. Brown strain birds were found on the upper tiers more often during the morning, with white strain birds more likely to roost on the upper tiers at night. Once litter access was made available at 26 weeks, white strain birds were quicker to utilise this resource (Ali et al., 2016). Brown strain birds are also more likely to show dust-bathing behaviour in FCs (Roll et al., 2008; Wall et al., 2008).

Traditional breeds such as unselected Brown leghorns, the Barred Plymouth Rock or crosses between such breeds, have significantly stronger bones than modern brown hybrids (Silversides et al., 2006; 2012; Regmi et al., 2016a). Brown laying hybrid strains have stronger bones than white hybrids (Riczu et al., 2004; Vits et al., 2005) but appear to suffer more from keel damage than white strains, or than brown parent stock (Kappeli et al., 2011a). This may be related to differences in body weight and wing load, leading to less controlled jumping and flying in heavier, brown birds (Moinard et al., 2004b; Scholz et al., 2014a) and hence collisions with greater impact. However, within Hyline Brown hybrids Donaldson et al. (2012) found no relationship between keel damage and individual bird parameters such as bodyweight, or wing-to-girth ratio.

LH11. WELFARE CONSIDERATIONS: OVERVIEW

Laying hens are housed in a wider range of housing systems than other species of farmed poultry and, for this reason, housing system itself is a major influence on bird welfare.

The conventional cage (CC) system prevents birds from performing basic movements essential for good health (walking, wing stretching), and denies birds the possibility of expressing their behavioural needs to roost, nest and forage, or their motivation to dust-bathe, due to an inherent lack of resources. Lack of exercise weakens bones which are likely to fracture during depopulation, and leads to metabolic conditions such as haemorrhagic fatty liver syndrome. Claw breakage, plumage abrasion and poor foot health are also features of CC systems. The general benefits of cage systems (such as reduced contact with faecal material, parasite load, infectious disease and relatively low mortality) are largely equalled or surpassed in furnished (enriched or colony) systems (FC). Immune function appears to be suppressed in hens housed in conventional cages compared with hens in FC systems, and levels of aggression are higher in CC systems. The welfare problems associated with CCs are substantial and their benefits can be achieved in other cage systems.

The FC system permits laying hens to perform a broader range of behaviours than the CC. Comfort movements, nesting and roosting can all take place at a rudimentary level although it is likely that behavioural needs are not fully satisfied in this system. Hens in FCs are not able to fly and foraging and dust-bathing opportunities are limited. Mortality in modern furnished cages is lower than in any other system. Birds in FCs have stronger bones than birds in conventional cages, a lower prevalence of injury during depopulation than hens from CCs, and a lower incidence of keel bone fractures during the laying period than hens from non-cage (NC) systems. The welfare problems associated with FCs are significant but these could potentially be reduced by lower stocking rates and improved provision of foraging and dust-bathing areas. A spatial allowance of at least 750 cm²/bird is required to ensure bird welfare. The health of birds in FCs is, on average, higher than that of hens from NC systems where far greater variation occurs.

NC systems tend to have highly variable outcomes for flock mortality, health, prevalence of keel fractures and injurious pecking. These systems are difficult to manage well and require attentive and experienced staff and managers. Monitoring levels of mortality, keel fractures and plumage scores in NC systems would enable targets to be set for progressive improvement. Recording broad causes of mortality (e.g. culls, predation, smothering) would facilitate progress. Attention to biosecurity, the use of ramps to access different levels within a house, careful positioning of house furniture, and the use of published management strategies to reduce feather pecking would be expected to lead to gradual reductions in these welfare problems. In NC systems, wire mesh floors have health advantages compared with plastic floors. These same considerations apply to free-range (FR) systems, although good use of the range can mitigate some of the problems encountered in indoor NC systems. Range use should be encouraged by the use of shrubs, trees and shelters.

The effects of stocking density for hens in NC systems have not been fully researched. Ensuring that resources are sufficient and are evenly distributed is important to avoid locally high stocking densities.

Low light intensity is sometimes used in an attempt to control inter-bird pecking but this can have adverse effects on eye function. It can be counter-productive if other foraging substrates appear less attractive than feathers.

Rearing pullets with appropriate enrichment discourages the development of feather pecking and helps to ensure that birds will be able to make full use of all facilities in the laying house as adults.

Infra-red beak trimming may be a necessary interim method of reducing the damage associated with inter-bird pecking, particularly during any industry transition towards NC systems. However, beak trimming has associated welfare problems. With advances in genetic selection and improved management, the prevalence of feather pecking would be expected to reduce. It may be possible to phase out the practice of beak trimming under these conditions.

Steps must be taken in all housing systems to control populations of red mite which can cause serious welfare problems for laying hens. Further research on methods of mite control is urgently required given growing resistance to current acaricides.

The practice of moulting hens by removal or restriction of feed causes severe welfare problems of bird hunger, stress and unacceptable levels of mortality. These problems are not reduced or mitigated by feeding low-nutrient diets. Modern strains of laying hen are now available with increased durations of the first laying cycle (90 weeks or more) greatly reducing any perceived need to moult. Reduced egg production towards the end of the first laying cycle can occur due to fat deposition and lack of exercise, but this is primarily a problem associated with CC systems. There are no welfare benefits that could outweigh the welfare costs of this practice.

LH12. REFERENCES

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LAYING HEN BREEDERS

LHB1. INTRODUCTION

Grandparent (pure line) layer stock are held in very high biosecurity facilities owned by just two or three worldwide genetics companies. The pure lines produce the parent stock hybrids (layer breeders). The layer breeders are kept in mixed-sex highly biosecure facilities and they produce fertile eggs to supply commercial rearing farms. Not all countries have laying hen breeding farms and the birds are not easily available for scientific study. The Netherlands, a centre for poultry breeding, had (in 2013) 5 facilities housing 97,000 grandparent birds and approximately 30 facilities housing 663,000 layer breeders (compared with 25 million laying hen birds on over 1,000 farms) (Landman and van Eck, 2015). Layer breeders are generally floor housed, whilst pure lines are housed in cages (de Haas et al., 2013).

LHB2. RISK MANAGEMENT

LHB2.1 Infectious disease

Laying hen breeder birds appear to be less susceptible to *E. coli* peritonitis syndrome than broiler breeder birds (Landman and van Eck, 2015).

LHB3. FEAR AND DISTRESS

De Haas et al. (2013) studied fearfulness and stress responses in 20 layer breeder flocks. Birds from white strains were more fearful of a stationary person and had worse plumage cover than birds from brown strains. High fear levels were associated with increased mortality in brown strains, and with low bodyweight and egg weight in white strains. In both strains high levels of the hormone corticosterone were associated with low egg weight, showing a clear link between stress and production.

LHB4. WELFARE CONSIDERATIONS: OVERVIEW

Layer breeders are held in secure facilities and are not easily available for independent scientific study. Liaison with facility owners to allow independent inspection and audit of the birds' housing conditions and the prevalence of any welfare problems, with a focus on problems known to occur in laying hens (injurious pecking, foot health, keel bone damage) or in broiler breeders (aggression, skin damage) would be beneficial.

LHB5. REFERENCES

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BROILERS

B1. INTRODUCTION

B1.1 Commercial systems

Chicken meat is a major source of animal protein in the human diet, with over 71 billion broilers slaughtered for meat globally in 2015 (source: FAOstat; www.fao.org/faostat/en/). Over the last 50 years broilers have been subjected to intense genetic selection for increased growth rate and body mass; growth rates having risen by over 300%, from 25 to 100 g per day (Knowles et al., 2008). In 1950 broilers took 16 weeks to reach marketable weight, compared to 32 days in most modern commercial strains, while the feed conversion ratio (the amount of feed eaten per kg of weight gain) has simultaneously reduced (Havenstein et al., 2003). Selection for fast early growth rate has resulted in significant morphological and physiological alterations, with associated welfare problems. Since broiler breeding programmes are dynamic, when unfavourable traits arise (such as an increased susceptibility to metabolic disease or leg disorders) these can usually be selected against (in combination with ever greater production capacity) over subsequent generations. This continuous selection process means that behavioural or physiological measures collected in previous decades may not be completely relevant today. Modern broilers are generally reared at high density in deep litter systems and comprise two main types: fast-grow (standard) breeds, which reach slaughter age in 32–40 days and which have been developed for rearing in an indoor barn environment, and slow-grow breeds, which reach slaughter age in 70 days and are better suited for free-range and/or organic systems. The majority of broiler welfare problems have a genetic basis and are further exacerbated by interactions with poor environmental management. Broiler welfare has received a lot of attention historically and the recent development and application of animal-based (outcome) measures of welfare now increase potential to highlight key issues and monitor interventions.

Broiler production is increasingly the preserve of specialist integrated companies with a controlling hand in all aspects of the production chain. Average flock sizes have increased markedly in the past decade, and in the UK the majority of birds are now reared on premises holding more than 100,000 birds. In most countries broilers are reared in indoor floor systems, with just small minorities kept in free-range or organic systems. The broiler production chain begins when chicks are transported, in controlled-environment lorries, from the hatchery to the rearing house. On arrival, small pellets or crumbs are spread on paper so that the chicks learn how to feed. For the first week the house lights are on for 23 h out of every 24, to encourage the new arrivals to feed and drink. By 3 or 4 days of age, chicks learn to feed from automated feeders and the paper is removed. Chicks are kept warm either by heating the whole house to an initial temperature of approximately 30 degrees, or by the provision of spot brooders. After 7 days, the EU Broiler Directive (Council Directive 2007/43/CE) requires that growing birds are allowed a total of 6 h darkness in every 24 h, to enable rest (EC, 2007). A resting period is not required in some non-EU countries, or it is specified only that birds must not be housed under continuous light, leaving open the option of a very short dark period. The birds grow rapidly on a sequence of starter, grower and finisher diets, and are usually slaughtered between 5 and 10 weeks of age. Many flocks (79% in a recent Belgian survey, Tuytens et al., 2014) are partially depopulated or “thinned” during the rearing period, with approximately 20% of birds removed for early slaughter. This allows for higher numbers of chicks to be placed initially without subsequently exceeding legal stocking density limits as the birds near slaughter weight.

B1.2 Backyard production

In hobby farms or smallholdings, traditional or specialist breeds may be kept for occasional meat supply. In developing countries, the majority of poultry are indigenous breeds, kept in small flocks living in a backyard, village environment (approximately 80 percent of poultry in Africa were found in such systems (Gueye, 1998) but the situation is changing rapidly as more intensive methods are adopted). In this type of poultry production system there is no real distinction between birds reared for meat and those kept as egg layers, with meat obtained from male birds killed at 12 to 20 weeks, and from non-productive layers. One advantage of keeping indigenous or traditional breeds is that they are generally better able to cope with the natural environment than those breeds that have undergone extensive genetic selection for production traits. However, disease transmission is high in backyard poultry systems, often resulting in low productivity and high mortality. Newcastle disease is one of the most problematic and widespread diseases in both village and intensive production systems. Vaccines have been developed, but not all farmers have access to them, and vaccinating free-ranging poultry can be a challenge (Nicol and Davies, 2013). In hot climates, birds may have difficulty staying cool if natural or artificial shelter is not provided, as all chickens are derived from jungle-living birds and they actively seek shade. Most of these welfare issues can be addressed by improved veterinary care and nutrition and the provision of simple facilities such as clean drinking-water and shade.

B1.3 Australian broiler production

Meat chicken production in Australia has been increasing for a number of years. On 30 June 2016 there were over 90 million chickens being reared for meat across 530 broiler farming businesses (ABS, 2017a), which was 6 million more

chickens than were being reared in June 2013 (ABS, 2014). There were 623 million broilers slaughtered in the financial year 2015-16 year (ABS, 2017c), with a gross value of over \$2.7 billion Australian dollars (ABS, 2017b).

B2. FEED AND WATER

Standard broilers usually receive 3 different diets: starter (1st week), grower (2nd to 4th week), and finisher (5th week), with a reduction in % crude protein at each step. The grower diet can be provided up to the end of the production period if it does not contain coccidiostats (antiprotozoal agents used to control the gut parasite *Eimeria*). The starter diet is usually fed as a crumb to facilitate rapid uptake by the chicks, while the other diets are usually fed as pellets (rather than mash) to prevent the birds from feeding selectively and, thus, reducing wastage. Feeding behaviour is negatively associated with increasing stocking density (see B9.1a).

B2.1 Genotypic differences in feeding behaviour

Selection for production parameters can inadvertently introduce 'invisible' behavioural traits, with potential consequences for welfare.

The selection for a new genetic trait linked to feed efficiency (wheat digestibility) was shown also to affect behaviour and different aspects of fearfulness; this highlights the potential risk of inadvertently affecting welfare when selecting for production parameters. Birds with high wheat digestibility (D+) expressed higher fearfulness in novel environments than birds with low wheat digestibility (D-) (Pelhaitre et al., 2012). In the presence of food, however, the D+ birds appeared more bold (they had lower latencies to approach novel food and were more motivated to explore for food than D-); interestingly, D- birds had a higher feed intake and lower food conversion ratio (Pelhaitre et al., 2012).

B2.2 Nutrition and litter quality

Poor litter quality (a key risk factor for contact dermatitis) can be linked to diet.

Contact dermatitis is very common in broilers and has strong associations with wet litter. Nutrition is one of the major factors affecting litter quality (see B3.4).

B2.3 Dietary restriction

The welfare benefits of feed restriction on health in fast growing broiler strains are overshadowed by the broilers experiencing extended period of hunger; fast-growing broiler breeds are inappropriate for use in extensive systems.

Feed restriction is used to curb growth for the benefit of health (e.g. reducing risk of ascites or lameness), especially when fast-growing breeds are used in organic production systems that specify a long rearing period. This is achieved via: (1) quantitative restriction of a high protein diet, whereby the feed is delivered as meals in a smaller quantity than would be voluntarily consumed *ad libitum*, and (2) qualitative restriction, whereby the diet is diluted with a low-nutrient 'filler'. Feed restriction is often associated with adverse and stereotypic behaviour. Free-range broilers fed a low-protein diet spent more time on the range and preened more than birds fed a similar diet supplemented with amino acids; however, they were also prone to cannibalism outbreaks, which are very rarely observed in broiler production (Eriksson et al., 2010). Increased preening is often observed following feed-restriction (e.g. Ipek et al., 2009) and is considered to be a response to mild frustration (Duncan and Wood-Gush, 1972, cited by Eriksson et al., 2010). Increased foraging has been specifically associated with low dietary lysine (Bizeray et al., 2002a) and, more generally, with restricted feeding regimens (Leterrier et al., 2008; Ipek et al., 2009; Eriksson et al., 2010). Quantitative, but not qualitative, feed restriction has been seen to increase activity levels (Nielsen et al., 2003a).

The means of limiting feed intake differentially affect the general well-being of broilers. Mendes (2008) observed that deviations in bilateral symmetry (fluctuating asymmetry) were lower in fast-growing broilers fed a quantitatively restricted diet compared to a control group fed *ad libitum* and a group subjected to a period of daily feed withdrawal, indicating higher developmental stability in these birds. In addition, broilers subjected to feed withdrawal had increased H:L ratios and fearfulness (tonic immobility) than a control or quantitative feed-restricted group (Karabayir and Mendes, 2008). Broilers subjected to early feed restriction had a lower final body weight and better welfare measures than *ad libitum* fed birds, including lower H:L ratio and reduced fearfulness (Toplu et al., 2016). Overt hunger is likely to be associated with any feeding regime that involves dietary restriction. Although there is no recent literature specifically addressing hunger in broilers there is ample evidence to highlight hunger as a major welfare issue in feed-restricted broiler breeders (see BB2.1).

The provision of nutritious vegetation on the range has been proposed as dietary supplementation for feed restricted broilers during the finishing period. Almeida et al. (2012) observed broilers to increase foraging activity with age and readily consume the vegetation provided.

B2.4 Mycotoxins and necrotic enteritis

Feed contamination by mycotoxins, in the presence of Clostridium, can have a devastating effect on broiler gut health; prebiotics may provide an effective alternative for antibiotic treatments.

Mycotoxins (e.g. aflatoxin) are produced by fungi (including *Aspergillus*) that contaminate food crops (Cravens et al., 2013). Broilers fed with a diet contaminated with mycotoxins demonstrate a physiological stress response (increased plasma corticosterone, H:L ratio: Ghareeb et al., 2014; Antonissen et al., 2017) and become more fearful, which can be reversed following treatment with a microbial feed additive (Mycofix®), a commercial antidote (Ghareeb et al., 2014).

Necrotic enteritis is caused by toxins produced by *Clostridium perfringens*. Outbreaks are associated with high dietary protein, stress, coccidiosis, intestinal parasites, and immune suppression by mycotoxins and various viruses. The induction of necrotic enteritis in broilers via exposure to *Clostridium perfringens* and the provision of a mycotoxin-contaminated diet induced intestinal lesions, reduced production parameters, and increased mortality; the two challenges interact to produce greater damage to health and growth (Cravens et al., 2013). Treatment with an antibiotic (virginiamycin) was seen to counteract some of these effects, improving gain, feed intake, and feed conversion, and decreasing mortality (Cravens et al., 2013); however, Al-Baadani et al. (2016) demonstrated that prebiotics were more effective at maintaining intestinal health and preventing the development of necrotic enteritis than antibiotic treatment.

B2.5 Dietary modifications for environmental reasons

It is possible to lower dietary phosphorus, while maintaining calcium levels, without impacting upon broiler welfare.

Calcium and phosphorus are important for skeletal and cellular functions in chickens; however, pressure to reduce dietary mineral content to lessen the environmental impact of broiler production has been growing steadily. Lowering dietary phosphorus from 6.6 to 5.5 g/kg had an adverse effect on bird welfare only when the level of calcium was also reduced (below 7.3 g/kg); this led to reductions in feed intake during the early growth period and skeletal strength (Ziaei et al., 2008).

B2.6 Probiotics

Salim et al. (2013) examined the effect of a direct fed microbial (DFM) containing *Lactobacillus reuteri*. Broilers fed with DFM had a better feed-conversion ratio, better blood indicators of immune function (white blood cell counts, monocytes, immunoglobulins) and lower *E. coli* faecal content than those fed a control diet, with most welfare indicators being the same as or better than antibiotic-treated broilers. In a similar study, Lei et al. (2015) found that a DFM containing *Bacillus* spp. also improved food conversion, weight gain and decreased *E. coli* population in the caecum compared to control-fed birds. Palamidi et al. (2016) also found that a commercial DFM (PoultryStar, BIOMIN, Austria) containing *Bacillus* spp. also improved weight gain and feed conversion ratio compared to controls fed the same diet in which the probiotic had been inactivated by heat treatment. Sen et al. (2012) also found that supplementing the diet of broilers with a DFM containing *Bacillus* spp. improved growth and gut health, and lowered caecal *Clostridium* and coliform counts.

B2.7 Water supply and health

The provision of adequate drinker access is important to avoid thirst and dehydration in broilers with reduced mobility, and to prevent skin lesions as a result of over-competition; however, spilt water may reduce litter quality and increase the risk of contact dermatitis.

The majority of broiler farms now use nipple and/or cup drinkers as opposed to bell drinkers. Water delivery systems that enable water to spill onto the litter can reduce litter quality, which can consequently increase foot pad dermatitis (FPD) or hock burn (HB) (see B3.4a and B3.4b); increased water consumption has also been directly associated with FPD (Manning et al., 2007). Nipple drinkers are provided in lines and positioned above the birds' heads. Birds with poor walking ability have been observed to lose balance while stretching to drink from a nipple (Jones et al., 2005a). Butterworth et al. (2002) observed gait score (GS: see B3.3d) to be positively associated with dehydration in a flock with poor leg health; measures of plasma osmolality (electrolyte-water balance) indicated that some birds may have been without water for more than 60 hours. The provision of adequate drinkers is important for reasons other than avoiding thirst and dehydration. More skin scratches have been observed with nipple-drinkers, than bell drinkers, presumably due to birds jostling for space; however, bell drinkers increase litter moisture, and this problem could be alleviated via the provision of more nipples (Allain et al., 2009). In a comprehensive field-study Jones et al. (2005a) identified that the availability of nipple drinkers per unit area was negatively associated with levels of leg rotation.

The addition of an extract of St John's wort (*Hypericum perforatum*) to broiler drinking water has been shown to increase body mass and immunoglobulin complex within the blood, and to decrease blood corticosterone and mortality (Skomorucha and Sosnowka-Czajka, 2013).

B2.8 Drinker design

Although nipple drinkers are commonly used to limit litter moisture (and reduce FPD) their position (above the broilers' heads) is not favoured by the birds.

Houldcroft et al. (2008) suggest that a redesign of drinker systems is required, to minimise wet litter while facilitating the preference of broilers to drink at a lower height. The action of pecking upward to obtain water is very different from the natural 'scoop' action that poultry perform when drinking from bowls. Management guides suggest that to minimise water loss nipple drinkers should be raised for growing birds to a height where the back of the bird forms an angle of approximately 75-85° with the floor and so that the birds are stretching slightly to obtain water (http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-Broiler-Handbook-2014i-EN.pdf). Another possible solution to the problem of wet litter caused by spills may be to provide grates below the drinkers (Foreman et al., 2013).

Broilers drink from bell drinkers and troughs in preference to nipple drinkers, and have a strong preference for drinking from nipples that are positioned at a lower height than currently provided; however, when offered a choice between bowls and nipples placed at the same height, broilers are indifferent to the method of water presentation (Houldcroft et al., 2008).

B2.9 Measuring thirst

Voluntary water consumption offers a simple animal-based means of assessing thirst on-farm, while physiological indicators of dehydration have been identified to distinguish between water withdrawal that has occurred during catching and transport, and dehydration that occurred on the farm.

Freedom of (prolonged) thirst is of paramount importance for animal welfare, yet animal-based measures of thirst are currently absent from monitoring schemes due to the difficulties associated with quantifying a subjective state. The Welfare Quality® assessment protocol for broilers uses the number of birds per drinking nipple, cup or bell drinker as an indicator of absence of prolonged thirst; to avoid thirst the recommendation is to provide a nipple for every 10 birds, a cup for every 28 birds or a bell drinker per every 100 birds (Welfare Quality®, 2009). Voluntary water consumption over time demonstrates potential for use as a non-invasive on-farm means of assessing thirst in broilers; it has been shown to increase with the length of water deprivation (Sprenger et al., 2009; Vanderhasselt et al., 2014). It is also possible to directly assess the level of dehydration via physiological measures. Vanderhasselt et al. (2013) identified creatinine and sodium as suitable indicators of medium-term water deprivation, allowing the distinction between water withdrawal during catching and transport, and dehydration that had occurred on the farm; levels of markers began to rise after 6 h and continued to increase following prolonged water withdrawal. In contrast, since plasma chloride was observed to increase after 6 h of water withdrawal, but not to rise further, it appears to be a suitable marker for use in the detection of dehydration between catch and slaughter (Vanderhasselt et al., 2013).

B2.10 Measuring water consumption

Water consumption (per area of floor space) could provide a 'trigger point' for alerting farm managers to litter deterioration.

Daily water consumption is currently monitored in l/bird/day to monitor flock performance and provide an indication of bird health. However, it has been shown that monitoring water consumption as l/m² floor area/day is a good lag (end of crop) indicator of litter quality (Manning et al., 2007). Manning et al. (2007) hypothesise that if a threshold level could be determined (in terms of l/m²/day) at which litter quality becomes compromised then this measure could provide managers with a "trigger-point" at which they would need to take remedial action to minimise contact dermatitis.

B3. RISK MANAGEMENT

Mortality in broiler production is generally less than 1.5% during the first week, and less than 5% in total (including culls) by the end of the growing period. Causes of mortality are metabolic disorders, ascites and infectious conditions, with birds being culled primarily because of leg disorders. Leg disorders affect the ability of broilers to perform normal behaviour and some types of leg disorder have been shown, in sophisticated experiments, to be associated with pain.

B3.1 Mortality

The main factors influencing early mortality include parental characteristics, incubation conditions, time of hatch, and brood temperature; in older birds the main causes of mortality are metabolic disorders, infectious disease (especially relating to gut health) and culling due to severe lameness.

For a standard broiler flock with a 32-40 day production cycle, mortality typically varies between 0.75 -1.32% per week, with producers aiming for <5% overall mortality (de Jong et al., 2012a).

B3.1a Early mortality

Up to one-half of all flock deaths occur during the first week of production (Kemmett et al., 2014); first week mortality is estimated at 1.5% (Heier et al., 2002; Yassin et al., 2009). Early mortality and the proportion of low-grade chicks are influenced by egg storage time at the hatchery (Heier et al., 2002; Tona et al., 2004; Yassin et al., 2009) and incubation conditions (Bruzual et al., 2000). Higher post-hatch chick mortality and a higher percentage of low grade (culled) chicks are associated with old parent flocks (Tona et al., 2004; Ipek and Sozcu, 2015; Iqbal et al., 2016; Nowaczewski et al., 2016) as well as very young breeders (Yassin et al., 2009). Chicks from young breeder flocks require special management during the first week due to a lower feed intake (Yassin et al., 2009) and body mass (Pedroso et al., 2005); this will include adjustments to the house and floor temperature, drinking nipple height, and the provision of higher dietary nutrients and energy sources. The increased mortality observed with chicks from old breeders is likely to be related to an earlier hatch rate (Almeida et al., 2008) and higher navel and navel-yolk sac infections (Yassin et al., 2009). Broiler breeder farm was highlighted as a risk factor for increased first week mortality (Heier et al., 2002; Yassin et al., 2009) and this is likely to be related to the health status of the breeder birds. Olkowski et al. (2015) provided evidence for eggshell quality (assessed using matrix optical density) to be associated with production losses, increased disease risk and mortality in broilers throughout the production cycle; heart failure, in particular, was significantly higher in the low-density group. The authors hypothesise that since poor nutritional/health status and metabolic changes in the breeder hen are likely to produce pathophysiological changes in the eggshell matrix morphology (and egg itself) it is reasonable to assume that poor maternal health can predispose their offspring to enduring health problems (Olkowski et al., 2015). The nutrition of breeder hens is known to affect the viability of progeny (Enting et al., 2007). Broiler breeder hens experience stress and hunger on a daily basis due to restrictions in feed intake designed to provide severe under-nutrition (see BB2.1) and this may also negatively impact the welfare of the subsequent generation.

Chicks hatch over a time window of approximately 36 to 48 h and are removed from the hatchers only when the majority of the chicks have hatched. Consequently, early hatching chicks experience delays in feed and water access, leading to dehydration and impaired performance (van de Ven et al., 2009). Delays in the delivery of first feed and water supply to birds in the hatchery have been related to increased mortality in broiler flocks (Chou et al., 2004). Post-hatch, the thermoregulatory system of chickens is limited (Nichelmann and Tzschentke, 2002, cited by van de Ven et al., 2009) and the provision of sufficient heat is critical to young birds. Early mortality in chicks has been linked to suboptimal truck temperatures, longer transport duration from the hatchery to the farm and open-curtain ventilation (Chou et al., 2004). Low temperatures in the brooding phase lead to increased early mortalities (Bruzual et al., 2000), while increasing stocking density reduced the cumulative mortality (Heier et al., 2002; Chou et al., 2004), presumably by facilitating increased huddling and raising the litter surface temperature. New broiler houses with automated control of air intake, and heating sources in the floor and/or wall, had lower chick mortality than flocks placed in older houses with manual ventilation and with gas or electric stove heating (Heier et al., 2002).

B3.1b Mortality in older birds

Mortality in older birds is often related to metabolic disorders and heart weakness (see B3.2) or caused by infectious disorders (see B3.6), while poor leg health and locomotion problems continue to be the major cause of culling (see B3.3f). In a study of 2.7 million birds from 10 different producer companies, Dawkins et al. (2004) reported total mortality by the end of the growing period to be 4.1%, of which 2.0% of birds were found dead, and 2.1% were culled. Naturally, fast-growing breeds are more susceptible to pathologies associated with fast-growth than the medium and slow-growing breeds and this is clearly demonstrated by studies which have assessed how different breed types perform in organic systems (Dal Bosco et al., 2014; Castellini et al., 2016; see B5.1).

Stocking density does not appear to be negatively correlated with mortality, at least in the absence of extreme ambient temperature (see B9.1b); environmental management within the broiler house has the largest impact on mortality. Decreased photoperiods (see B8.1a) and restricted feeding regimes decrease mortality (see B3.2b), although mortality appears to be unaffected by light intensity (see B8.1b). High temperature and relative humidity (RH), and the percentage of time that these are out of range, increase the prevalence of heat stress, leg deformities and mortality (see B8.4a). The provision of enrichment such as straw bales has been associated with improved leg health and may indicate a reduced requirement for leg culls (see B5.3). The use of ozone as a treatment to improve air quality within broiler sheds is deemed inappropriate due to high broiler mortality rates associated with ozone exposure (see B9.2). A fatty acid dietary supplement (2 g/kg Aromabiotic) has been shown to improve early productive performance of broiler chickens and decrease mortality at 49 days (Khosravinia, 2015).

B3.2 Metabolic disorders

Ascites appears to be on the increase, in at least some countries, yet it should be possible to reduce the prevalence of this disease via the use of appropriate temperature control and genetic breeding programmes.

B3.2.a Prevalence and cause

Ascites is a cardiovascular metabolic disorder of fast-growing broilers. An insufficient supply of oxygen to the myocardium, e.g. following respiratory failure or as a result of an excessive demand for oxygen, triggers dilatation and hypertrophy of the right side of the heart, which leads to cardiac failure and alters liver function, causing fluid accumulation in the abdominal cavity. As with ascites, sudden death syndrome (SDS) is also thought to result from a lack of oxygen to the myocardium. Ascites is one of the most prevalent broiler health and welfare conditions identified in UK-reared broilers at slaughter/processing; both the prevalence and the number of carcase condemnations are on the increase (Part et al., 2016, see Table B1).

Table B1: National annual prevalence rates of health and welfare conditions in UK-reared broilers, number of cases of each condition identified at slaughter per 10,000 birds slaughtered (Part et al., 2016)

Condition	Year		
	2011	2012	2013
Ascites	26.46	30.25	33.01
Bruising/fractures	30.36	24.54	29.14
Hepatitis	22.81	25.12	23.32
Abnormal colour/fevered	22.10	22.68	22.08
Cellulitis	11.35	15.05	18.03
Dead on arrival/dead in lairage	12.81	13.19	14.25
Perihepatitis/peritonitis	8.06	8.32	9.35
Ante-mortem rejects (culls/runts)	2.82	4.52	5.40
Pericarditis	4.68	3.97	4.07
Emaciation	4.12	3.36	3.13
Other farm-related conditions	n.a.	1.46	3.79
Joint lesions	2.16	2.77	2.92
Tumours/nodules	1.94	1.97	2.14
Dermatitis	2.39	1.91	1.68
Respiratory disease	1.70	0.32	0.27
Salpingitis	0.04	0.07	0.03
No. slaughtered	79,151,084	813,413,852	826,325,841
<i>Conditions listed in descending order of weighted average (2011-2013) annual rates. Based on data from the Food Standards Agency, UK.</i>			

The most important environmental factors causing the development of ascites in commercial broilers are high altitudes and cold temperatures (Ipek and Sahan, 2006; Özkan et al., 2010; Part et al., 2016); ascites incidence tends to fluctuate in seasonal patterns that reflect ambient temperature. When Part et al. (2016) excluded outliers they concluded that broiler mortality rates (to which ascites is a major contributor, see Table B1) began to rise on average when maximum temperature exceeded approximately 19 °C or fell below approximately 8 °C. Özkan et al. (2010) described male mortality rates (largely due to ascites) of 0.4% (birds reared at sea level at 22-24 °C), 13.8% (birds reared at high altitude 1,720 m at 22-24 °C) and 44.2% (birds reared at high altitude 1,720 m at 16-20 °C).

Fast growth rates are associated with higher feed intake and metabolic rate, and consequently a higher demand for oxygen. As growth rate and oxygen demand coincide with other physiological challenges, such as low ambient temperature, this can cause problems in regulating oxygen supply to heart tissue (Druyan et al., 2008). Broilers reared in

cold conditions tend to eat more (e.g. Nielsen, 2012), which will further increase their oxygen requirements (Part et al., 2016). Mortality has been found to be higher in males than in females (Özkan et al., 2010), presumably linked to a higher body mass. Imaeda (2000) observed an effect of stocking density upon seasonal mortality; a high stocking density (18 broilers/m²) was associated with increased total mortality and SDS mortality in the summer, and with an increase in SDS mortality in the winter compared to lower densities (12 and 15 broilers/m²).

B3.2b Prevention and control

Considering the influence that cold temperatures have on the aetiology of metabolic disease, the best intervention is to maintain the broiler house at an appropriate temperature year-round (Part et al., 2016). Incubation temperatures also appear to be important; Molenaar et al. (2011) showed that a high eggshell temperature (EST) of 38.9 °C from day 7 of incubation resulted in a 4% increase in ascites compared with a normal EST of 37.8 °C. Several studies have demonstrated that quantitative feed restriction is useful in controlling mortality due to ascites (Boostani et al., 2010; Özkan et al., 2010; Camacho-Escobar et al., 2011), as is dietary micronutrient supplementation (Camacho-Escobar et al., 2011). Reducing day-length reduces mortality from metabolic disease, possibly due to a lowered growth trajectory (Hassanzadeh et al., 2003; Lewis et al., 2009b; Schwan-Lardner et al., 2013). Scott (2002) found that a delayed decreasing increasing (DDI) lighting programme (which provided variable extended dark periods throughout rear) lowered mortality associated with both SDS and ascites, compared to a continuous or a constant restricted photoperiod (16L:8D); however, DDI was associated with production losses which made it uneconomical for commercial application.

Much research has been conducted to control or reduce ascites through genetic approaches, since susceptibility to ascites has a hereditary background. It has been demonstrated, via appropriate selection, that it is possible to develop a resistant line without compromising broiler performance (e.g. Pakdel et al., 2005; Druyan et al., 2008).

B3.3 Leg disorders and lameness

Lameness is associated with heavy, fast-growing, broilers and is of serious welfare concern due to an inability of lame birds to access resources, limited behavioural expression, and pain; preventative measures include the encouragement of activity from an early age to improve leg strength, an appropriate photoperiod, and the use of genetic selection in breeding programmes.

Lameness can take many forms. It can be infectious (see B3.3b), arise due to developmental bone deformities (see B3.3c), or be degenerative (e.g. due to the consequence of trauma or load-bearing throughout life), and it can involve tendons, joints, ligaments, and bones (Bradshaw et al., 2002). Strong correlations between body mass, growth rate, and lameness have been documented (e.g. Kestin et al., 2001), although there is little evidence to link the severity of lameness with pathology (Garner et al., 2002; Sandilands et al., 2011; Fernandes et al., 2012), which complicates the issue in assigning pain (see B3.3f). Poor leg health and locomotion problems continue to be the major cause of culling, late mortality and poor welfare in broilers.

B3.3a Prevalence and relation to growth rate

Genetic selection has altered the morphology and walking ability of modern broilers. The breast muscle has been specifically targeted (producing a condition termed pectoral hypertrophy) which makes modern broiler breeds front heavy, in addition to having a greater thigh muscle and leg bone mass, and relatively short legs (Corr et al., 2003a). Differences in gait identified between modern broilers and Red Junglefowl, their ancestral line (Caplen et al., 2012), will likely be due to a combination of greater body mass, abnormal morphology, and often (but not necessarily) pathology. In response to an injury, heavy load, or unbalanced posture, an animal will perform compensatory gait adaptations to minimise the additional energy expenditure required for movement (Corr et al., 2003b). Modifications, such as the wide stance and hip and foot rotations, rapidly tire the birds (and explain low activity levels), but may also lead to progressive leg pathologies (Corr et al., 2003a; 2003b).

In studies of UK flocks, Dawkins et al. (2004) found that 0.9% of all broilers scored were 'reluctant to move and unable to walk many strides before sitting down', while a later field-survey reported that by the end of rear 27.6% of birds showed poor locomotion and 3.3% were almost unable to walk (Knowles et al., 2008). The prevalence of valgus (more common, feet splayed outwards) and varus (feet splayed inwards) deformations have been reported as 37% (Denmark: Sanotra et al., 2001) and 23.3% (UK: Dawkins et al., 2004), but this figure is likely to have changed since breeding companies are constantly selecting for improved leg health. Tibial dyschondroplasia (TD) prevalence data varies widely between studies, presumably because some have targeted flocks with known leg problems; a Danish study reported a very high prevalence of 57% (Sanotra et al., 2001), while the incidence of TD reported in an experimental flock (USA) was only 9.2% (Tablante et al., 2003).

B3.3b Infectious lameness

Femoral head necrosis (FHN), or bacterial chondronecrosis with osteomyelitis, is one of the most widespread and prevalent endochondral bone growth problems within European broilers, although the pathology is being successfully

addressed with improved hatchery hygiene. FHN is associated with lesions in the metaphysis, femoral head, proximal femoral growth plate and joint; in a recent study necrosis was most commonly caused by osteomyelitis, which was associated with *E. coli* infection in more than 90% of broilers with FHN (Dinev, 2009).

B3.3c Developmental lameness

Commonly observed skeletal abnormalities include angular deformities (valgus-varus) and rotational (torsional) deformities such as twisted leg. These are observed in the distal limb and involve lateral or medial deviation and/or external rotation. The pathogenesis of the valgus and varus deviation of the intertarsal joint is not well defined. The deformity may occur as a consequence of poor bone mineralisation and may have links with rickets. Leg angulations can occur in different severities; Shim et al. (2012a) classify valgus as mild (tibia-metatarsus angle between 10-25°), intermediate (25-45°), or severe (>45°).

Although less prevalent in recent years due to selective breeding programmes, tibial dyschondroplasia (TD) remains one of the most common skeletal abnormalities associated with fast growth in broilers and can lead to lameness; it occurs as a defect in the prehypertrophic cartilage of the growth plate (Dinev et al., 2012). The TD lesion is characterized by an abnormal white, opaque, unmineralised, and unvascularised mass of cartilage occurring, most commonly, in the proximal end of the tibia. Bones from birds with TD are generally less well mineralised and have lower percentage bone ash than healthy birds (Tablante et al., 2003).

Rickets is relatively uncommon within modern broiler flocks. The leg disorder develops as a result of nutrient (vitamin D, calcium, and phosphorus) malabsorption (e.g. following intestinal disease), or due to inadequate nutrition (e.g. dietary errors). Incidence of calcium (hypocalcemic) rickets is significantly influenced by dietary calcium; a higher incidence was observed in birds fed diets with 0.2% less Ca than the 2:1 Ca:nPP (non-phytate phosphorus) ratio (Coto et al., 2008). Rickets is associated with defective flexible long-bone formation as a result of abnormal endochondral ossification and failed mineralisation leading to skeletal deformities (valgus-varus); this may increase the risk of the flock developing additional pathological states (FHN, TD) during the finisher period (Dinev and Kanakov, 2011). Corr et al. (2003b) observed that *ad libitum* fed fast-grow broilers had wider tarsometatarsus bones but the bones had a lower calcium and phosphorus content than slow-grow broilers, which would theoretically make them weaker.

B3.3d Measuring leg health

Several gait scoring methods have been developed for assessing broiler lameness in the field, based upon visual appraisal of walking ability. These range from simple three point scales (0: completely normal, 1: walking impaired; 2: unable to walk, Dawkins et al., 2004) to the widely used Bristol six-point 'gait score' (GS) scale (BGSS: Kestin et al., 1992), now adopted in a modified form for use within the broiler Welfare Quality® Assessment (GS 0: Normal, dextrous and agile; GS 1: Slight abnormality, but difficult to determine; GS 2: Definite and identifiable abnormality; GS 3: Obvious abnormality, affects ability to move; GS 4: Severe abnormality, only takes a few steps; GS 5: Incapable of walking, (Welfare Quality®, 2009). Although gait-scoring systems are suited for use on-farm, being quick to employ and requiring no specialised equipment, as subjective methodologies they lack the capacity to discriminate between lameness type. A moderately lame 'GS 3' bird could be affected bilaterally (e.g. valgus) or unilaterally (e.g. singular hock inflammation), or lack any obvious pathology. Objective methodologies for quantitatively assessing gait are now available (e.g. kinematic analysis: Caplen et al., 2012; 2013a), but these are currently only suitable for experimental 'laboratory' use.

Another widely-used measure of leg health is the latency-to-lie (LTL) test. This records the time-taken for a broiler to sit, from standing, when placed in (mildly aversive) shallow water (Weeks et al., 2002; Berg and Sanotra, 2003). Efforts are currently being made to develop automated technologies that can be used on farm to remotely monitor flock leg health. An automatic monitoring system has recently been developed that quantifies the number of lying events and the latency to lie down in broiler chickens while they walk a test corridor; the authors report good correlations with these measures and GS (Aydin et al., 2015). In a step towards achieving an automated means of assessing broiler welfare via behavioural surveillance, optical flow measures of flock movement have been shown to correlate with welfare outputs such as mortality, HB, FPD and lameness (Dawkins et al., 2009; 2013; Roberts et al., 2012). Optical flow refers to a change in the rate of change in brightness in each area of an image frame over time. Dawkins et al. (2013) found that when healthy, normal walking becomes unusual within a flock (e.g. the number of birds that walk for at least 10 s is infrequent) this can be detected by looking at the distribution (kurtosis and skew) of the optical flow distribution curve.

B3.3e Lameness risk factors

The key risk factors associated with lameness and poor leg health in modern broiler genotypes are those specifically associated with rate of growth, including genotype (growth rate), age, body mass and feeding regimen. High live-weights and rapid growth rates result in abnormally high loads being placed on relatively immature bones and joints. The more traditional and slower-growing genotypes demonstrate lower lameness than modern fast-growing breeds reared on the same feeding regimen (Kestin et al., 2001); however, genotypic differences in leg health have also been identified between fast-grow breeds (Knowles et al., 2008). Bone health (tibia breaking strength and tibia density per unit of body mass) is also better in slower-growing (no more than 50 g weight gain/day averaged over growing period; e.g. Label

Rouge; Cornish Rock; Cobb Sasso) than fast-growing broilers (e.g. Ross 308; Cobb 500). Fast-growing breeds have highly porous cortical bones which leave them susceptible to developing bone abnormalities and leg deformities (Shim et al., 2012b). A Bulgarian study highlighted differences in TD incidence associated with genotype: Pureline (27.7%), Cobb 500 (26.5%) and Ross 308 (24.22%) (Dinev et al., 2012).

Lameness increases with age (Sorensen et al., 2000; Kestin et al., 2001; Weeks et al., 2002; Brickett et al., 2007; Knowles et al., 2008; Bailie et al., 2013; Bassler et al., 2013; Bailie and O'Connell, 2015; Henriksen et al., 2016), and body mass (Weeks et al., 2002; Kristensen et al., 2006a; Venäläinen et al., 2006; Brickett et al., 2007; Nääs et al., 2009; Henriksen et al., 2016). As does valgus-varus (age: Fernandes et al., 2012; mass: Sanotra et al., 2001; Shim et al., 2012a). Dinev et al. (2012) observed that TD-lesions were first seen in broilers at the average age of 24 days (Ross 308), 20 days (Cobb 500) and 29 days (Pureline); this provides evidence for TD lesions developing at younger ages than reported previously, which the authors hypothesise as being due to continued selection pressure for increased developmental rates. Males are generally seen to have higher GS than females (Sorensen et al., 2000; Brickett et al., 2007; Paz et al., 2013; Henriksen et al., 2016), and are more prone to developing valgus-varus (Sanotra et al., 2001; Oviedo-Rondón et al., 2009a; Paz et al., 2013) and femoral degenerative joint lesions (Paz et al., 2013), especially if they are heavier. Although some studies observe no difference in the incidence of TD between the sexes (Tablante et al., 2003; Dinev et al., 2012), others report a higher incidence in male than female broilers (Sanotra et al., 2001; Birgul et al., 2012). These findings are likely to be linked to the weight of the birds, since TD is also positively associated with growth rate and mass (Sanotra et al., 2001; Shim et al., 2012a).

The choice of system (with the appropriate broiler genotype) has an obvious impact upon broiler leg health. For example, no lameness was observed in slower growing Cobb Sasso broilers reared under enriched environmental conditions (perches, straw bales, pecking blocks, winter garden) at a lower stocking density, whilst 0.8% of conventionally reared Ross 308 broilers showed signs of lameness (Bergmann et al., 2016).

The presence of a dark phase (scotophase) is conclusively beneficial for broiler leg health (Sanotra et al., 2002; Brickett et al., 2007; Knowles et al., 2008; Petek et al., 2010; Bassler et al., 2013; Schwan-Lardner et al., 2013; Das and Lacin, 2014). This may be because birds given a dark period are physically more active during the light period than birds kept under near-continuous light (Sanotra et al., 2002; Bayram and Özkan, 2010; Schwan-Lardner et al., 2012). Physical activity supports bone development (Reiter and Bessei, 2009), so increased activity during the light period may help reduce lameness in broiler flocks (Ventura et al., 2012; Bailie et al., 2013). In addition, bone mineralisation peaks during the dark period and is also sensitive to diurnal rhythm (Russell et al., 1984, cited by Bassler et al., 2013).

Key management factors affecting bird leg health are those relating to environmental control, particularly good ventilation (air quality), temperature, RH and litter quality. High temperature and low RH within broiler houses, and the percentage of time that these remained outside of the breeder's recommended range, were all found to adversely affect gait, and increase unilateral leg deviations (Dawkins et al., 2004; Jones et al., 2005a). The absence of automatic control over temperature (i.e. manual control only) was associated with lower levels of best gait (GS 0), while higher ammonia levels were also positively linked to unilateral leg deviations (Dawkins et al., 2004; Jones et al., 2005a). Misting systems were associated with more leg rotations, mortality and, presumably the additional adverse effects of wet litter (Jones et al., 2005a). Broilers reared under colder environmental temperatures displayed altered long bone growth, including reductions in femur, tibia and humerus length and tibia weight (Bruno et al., 2007). Higher stocking densities are associated with higher GS and poor tibial development but not with valgus-varus deformities or TD (see B9.1b).

Inappropriate incubation conditions can negatively impact upon embryonic development and, subsequently, broiler production parameters, health and welfare; appropriate temperature and oxygen concentrations are, therefore, critical for post-hatch health. Bone development (and leg health) can be manipulated by EST, which provides a reliable reflection of embryo temperature. Groves and Muir (2014) report that lower EST between days 1–15 (approx. 37.5 °C), and higher EST between days 16–18 of incubation (approx. 38 °C), delay hatch time and produce birds with greater leg strength (as measured by LTL) at 6 weeks of age. This indicates that the optimum EST during incubation for broiler leg strength development is lower than the optimum temperature currently recommended for maximising hatchability and chick growth (37.8 °C). This is further supported by observations of lower hatchability, chick quality, tibia and metatarsus lengths, altered growth plate development, and higher GS following egg incubation at higher temperatures than currently considered optimal (van der Pol et al., 2015; Ipek and Sozcu, 2016; Oznurlu et al., 2016). Oviedo-Rondón et al. (2008) demonstrated that incubating eggs at above-optimum temperatures and under conditions of hypoxia (<21% oxygen) during the final 4 days of embryo development increased leg asymmetry and stunted long-bone development, especially in broiler lines with low eggshell conductance. Flock incidence of TD has been associated with (suboptimal or supraoptimal) temperature deviations during the early stages of embryo development (Yalçın et al., 2007). Small changes in the EST during incubation could occur in practical conditions due to large capacity incubators and the high growing rate of broiler embryos. Oviedo-Rondón et al. (2009b) observed that the incidence of valgus and hockburn (see B3.4b) in 8 week old commercial broilers were linked with incubation conditions; broilers hatched from multistage incubators had higher GS, leg deformations and lesions than those hatched from single-stage incubators. Exposure of chicks to transportation stress, including elevated temperature (40 °C), increased the incidence of twisted legs in 41 day old broilers compared to a control transportation treatment (34 °C) (Oviedo-Rondón et al., 2009a).

In addition to bone development being adversely affected by early life environmental stress, several studies have also identified some interesting associations between broiler breeders and the leg health of their offspring. Broiler progeny produced from older (44-week) breeders were more lame (higher GS) at 6 weeks than broilers arising from younger (32-week) breeders; however, no difference in the incidence of angular deformations or twisted legs were observed (Eusebio-Balcazar et al., 2015). Increasing broiler breeder access to feeder space at lay (and feeding a maize-based diet) has been seen to alter bone development in progeny; leg bone weight/length and femur length asymmetry were increased compared to progeny of breeders with access to standard feeder space (Eusebio-Balcazar et al., 2014). The same authors also report worse leg health and higher mortality in broilers originating from breeders given greater feeder space, which is likely to be (at least in part) due to superior growth rates in these progeny (Eusebio-Balcazar et al., 2015). In addition, maternal stress may also influence offspring development; increased feeder access has also been associated with higher breeder mortality (see BB3.2) and prenatal corticosterone has been linked with bone asymmetry post-hatch in laying hens (Eriksen et al., 2003, cited by Eusebio-Balcazar et al., 2015).

B3.3f Welfare impact of lameness

Presence of valgus-varus deformations are positively correlated with lameness (Sanotra et al., 2001; Fernandes et al., 2012). Sanotra et al. (2001) also found TD to be linked to GS, although other studies observed no relationship (Garner et al., 2002; Fernandes et al., 2012). This suggests that other factors have more influence upon walking ability than TD. Lameness alters the time budget of broilers and reduces the breadth of behaviours that they are physically able to perform. Sound broilers spend the majority of their time lying (76%) and such inactivity increases with age and lameness (BGSS GS 3: 86%); lame birds lay down to eat for almost half of their feeding time, while sound birds usually choose to feed standing (Weeks et al., 2000). Mobility (walking) declines with age and with lameness (Weeks et al., 2000), and if severely compromised can have additional welfare consequences; dehydration has been reported as a direct consequence of lameness (Butterworth et al., 2002).

Immobility has obvious welfare implications if birds are unable to access drinkers and feeders, but the prevalence and severity of pain associated with lameness in poultry remains poorly understood. Pain assessment in non-human species is complicated by an inability to communicate verbally and must therefore be inferred using indirect measures. Non-steroidal anti-inflammatory drugs (NSAIDs) may have therapeutic potential in poultry. Although there is some evidence for NSAID treatment improving lame broiler walking ability, the studies have targeted different pathologies and used a variety of doses, routes of administration, and end-measures to make direct comparison difficult.

Evidence for lame broilers (BGSS: GS ≥ 3) experiencing pain and discomfort was provided by Danbury et al. (2000), who observed preferential selection of NSAID-spiked feed in a self-selection experiment. Colour cues and training periods were used to enable birds to discriminate between feed types. However, this study was subject to variations in feed consumption (inter-bird) and lameness severity (intra-bird) and lame birds failed to demonstrate higher carprofen plasma concentrations than non-lame birds at the end of the trial. A recent study failed to corroborate evidence that lame broilers would self-select NSAID-treated food (Siegel et al., 2011), which further questions the suitability of a broiler self-selection paradigm. It is possible that chicken behaviour may not accurately reflect a pain state since 'resting' is a baseline broiler behaviour (Weeks et al., 2000), and prey species are less likely to display overt pain-associated behaviour that may increase predation risk.

There is debate as to whether all lameness is associated with leg pain; some abnormal gaits will undoubtedly occur as a result of morphological changes and mechanical limitations (Corr et al., 2003a; 2003b). Skinner-Noble and Teeter (2009) hypothesise that broilers with (BGSS) GS 2 and GS 3 have similar well-being, the difference in gait (at least in their study) being morphological rather than due to pain. Although birds of either GS had similar production parameters (body weight, feed conversion ratio), fearfulness (tonic immobility) and H:L ratios, the different physical proportions (greater breast muscle) associated with GS 3 broilers was considered adequate to explain the gait alterations and inactivity levels displayed by these birds (Skinner-Noble and Teeter, 2009). Strong physiological evidence exists for broilers to have the ability to experience leg pain. Slowly adapting mechanoreceptors are present within the skin of the chicken tarso-metatarsus and these are sensitised following induced inflammation (Gentle et al., 2001); inflammatory arthropathy has also been identified within spontaneously lame broiler hock joints (Corr et al., 2003c). Caplen et al. (2013b) found direct evidence for an association between experimentally induced inflammatory arthropathies (an acute pain model) and thermal (primary) hyperalgesia in broilers, and demonstrated that NSAID treatment could reverse the induced-hyperalgesia (via anti-nociception). Hothersall et al. (2014) were unable to demonstrate primary thermal hyperalgesia in broilers with moderate 'spontaneous' lameness (BGSS: GS 3). Unexpectedly, in this study thermal threshold was higher in lame birds and, following NSAID treatment, thermal threshold increased further in lame birds and decreased in non-lame birds (Hothersall et al., 2014). The authors hypothesise that 'spontaneous' lameness may alter nociceptive processing, and report difficulties in linking lameness severity with pathology, similar to Sandilands et al. (2011).

As expected, lame broiler chickens (BGSS GS 3-4) performed poorly in standardised mobility tests compared to non-lame birds (Caplen et al., 2014; Hothersall et al., 2016). Although measures from an obstacle test (number of obstacle crossings, latency to first cross the obstacle) were unchanged following NSAID treatment in lame broilers, LTL was improved, when compared to a control group receiving saline (Hothersall et al., 2016). Relationships between broiler

lameness and pain (and thus welfare) are complicated by confounding factors such as bodyweight, sex and pathology. Caplen et al. (2014) report that 'lameness' (BGSS: GS 3-4) was observed to be the most consistent predictor for several broiler mobility measures. This provides evidence for a component of 'lameness' that could not be explained by bird characteristics (e.g. being male and heavy); this component may represent pain or discomfort (Caplen et al., 2014). NSAIDs have also been observed to alter gait and increase walking velocity in moderately lame broilers (Nääs et al., 2009; Caplen et al., 2013a); however, improvements in mobility could reflect reduced joint inflammation rather than an analgesic effect. Müller et al. (2015) observed that very lame birds (BGSS: GS 4-5) had lower body masses and a greater relative adrenal mass than broilers without, or with mild, gait abnormalities (GS 0-2), which may be indicative of chronic stress. Overall, the evidence suggests that NSAIDs do have an analgesic effect on lame birds, at least some lame birds experience pain, and that lameness has the potential to compromise broiler welfare on several different levels.

B3.3g Prevention and control of lameness

Although elevating brooding temperature (37 versus 33 °C) increased chick activity (and temporarily reduced chick weight gain) during the first week post-hatch, this did not result in a clear reduction in lameness (as measured by GS) towards the end of rear (Henriksen et al., 2016).

Diet and feeding regimes are important factors in the prevalence of lameness, both via the control of growth rate and for increasing bone strength. Birds reared on a qualitatively restricted (low energy) diet were less lame than birds of the same genotype reared on a non-limiting diet (Kestin et al., 2001). Sequential feeding of a high-energy/low-protein diet and a low-energy/high-protein diet on subsequent days was shown to significantly increase standing time and decrease lameness, without altering bone quality (Letterier et al., 2008). Similarly, sequentially fed broilers, provided a low lysine diet in the morning and a standard lysine diet during the afternoon, were lighter than control broilers and had lower GS (Bizeray et al., 2002a). Quantitative dietary restriction has been shown to reduce ascites and leg problems in Ross and Cobb broilers (Wijtten et al., 2010). Eriksson et al. (2010) observed that fast-grow broilers maintained under an extensive system for 70 days and fed a low crude protein diet supplemented with amino acids (LCPA) demonstrated greater body mass, poorer leg health and higher mortality than birds receiving a similar diet but without the addition of amino acids (LCP). This study highlights the unsuitability of fast-growing breeds for use in extensive systems. Feed restriction is associated with feelings of hunger and this has obvious adverse impacts upon bird welfare (see BB2.1 and BB2.2). Not every study reports benefits of nutritional management, however; Konca et al. (2008) failed to observe any improvement in GS in broilers fed via either a 'meal-time' regime or a low protein diet compared to a control group fed *ad libitum*.

Broilers fed their diet as mash had higher bone ash and lower GS than broilers fed their diet in pellet form (Brickett et al., 2007), presumably due to the birds eating a greater volume of pelleted food (with associated weight gain), while those fed mash could preferentially select components of their diet with physiological benefits. Whole wheat is sometimes fed to broilers as part of their diet to improve digestive function, and wheat provision has also been associated with improved leg health (Knowles et al., 2008), perhaps due to improved litter quality.

Increasing dietary calcium (Ca) is beneficial for increasing bone quality and reducing TD. Abdulla et al. (2017) observed that broilers fed 1.25% dietary Ca had significantly improved tibial bone quality than broilers fed 1%. Leg health appears to be correlated with the dietary ratio of Ca and non-phytate phosphorus (nPP), rather than absolute concentrations. Tibia ash and LTL measures were reduced by diets having either 'high Ca: low nPP' or 'low Ca: high nPP' (Bradbury et al., 2014), while broilers fed diets with 0.2% less Ca than the 2:1 Ca:nPP ratio displayed significantly higher TD incidence and severity compared to those fed higher levels (Coto et al., 2008). Dietary supplementation with 25-hydroxycholecalciferol has been shown to reduce TD incidence (Coto et al., 2008). Oso et al. (2011) provide evidence against the use of wood ash as a non-phytate Ca source in broiler feed as it has been linked with a significantly higher prevalence of lameness than alternatives including oyster shell, snail shell, and limestone.

Increased dietary vitamin D3 increases the morphological symmetry of the tarsometatarsus and tibial bone quality, and reduces GS (Baracho et al., 2012; Sun et al., 2013), while the provision of ascorbic acid (150 mg/l in water) has been found to increase the cortical thickness of the tibiotarsus and decrease TD incidence (Petek et al., 2005).

Reiter and Bessei (2009) provide evidence for increased activity levels being beneficial for broiler leg health. Fast growing broilers trained to walk on treadmills displayed increased bone density and thickness, and reduced bending and twisting in leg bones, while spacing feeder and drinkers further apart (12 m vs 2 m) was seen to increase locomotor activity and reduce lameness, without compromising production parameters (Reiter and Bessei, 2009). Since this study there has been some interest in designing feeding regimes to stimulate increased broiler activity levels. Scattering feed pellets in the litter significantly increased activity (including locomotion) in a fast-growing broiler breed, which was not achieved by scattering whole wheat in the litter (provided as a supplement to feed pellets within a feeder); however, a substantial reduction in growth rate was associated with feed scattering (Jordan et al., 2011), presumably due to a portion being lost in the litter, which limits the application of this feeding regime in a commercial setting. Pichova et al. (2016) report that the motivational significance of food items scattered on the litter surface influenced litter-directed behaviours in broilers; mealworms (a highly attractive food source) induced increased foraging activity (litter-pecking and scratching) for 10 min post-treatment, whereas the provision of whole wheat (a less attractive food source), or wood-shavings, in a similar

manner failed to trigger any increase in foraging activity. Unfortunately, since the increase in activity promoted by mealworm delivery was so transient it is unlikely that such a feeding regime could improve broiler leg health.

The provision of perches to promote exercise and activity has been suggested as a means to reduce broiler leg problems; however, it remains unclear as to whether perch provision can prevent TD. In a study investigating perch use by broilers Tablante et al. (2003) observed the incidence of TD to be lowest in birds raised at higher densities (15-20 vs. 10 broilers/m²); interestingly, TD was not observed in the control groups (without perches). Although perching frequency increased with stocking density, overall, it was performed infrequently (Tablante et al., 2003). Since the perches remained fairly unused they may have, instead, acted as barriers, reducing bird activity further and increasing TD as a consequence.

The widespread adoption of meal feeding, in combination with longer dark periods, is thought to be a major factor in leg health improvements seen in UK broilers over recent years. The light schedule broilers are kept under affects both their general activity level and their feeding behaviour (Sanotra et al., 2002; Bayram and Özkan, 2010; Schwan-Lardner et al., 2012). A photoperiod with a longer continuous scotophase appears to be particularly beneficial for improving walking ability. Broiler lameness (GS) was higher under continuous light (24L:0D) than constant restricted light (16L:8D: Sanotra et al., 2002; Schwan-Lardner et al., 2013; Das and Lacin, 2014) or intermittent lighting (4L:2D: Das and Lacin, 2014). Lameness was also higher under a short scotophase (20L:4D) than a longer scotophase (12L:12D: Brickett et al., 2007). Positive associations between hours of light and lameness have also been identified in large commercial field studies (Knowles et al., 2008; Bassler et al., 2013), as well as associations reported between daylight hours, FPD and mortality due to poor leg health (Schwan-Lardner et al., 2013). Although TD has been observed to be higher under continuous light (24L:0D) than constant light (16L:8D: Sanotra et al., 2002) or intermittent light (12L:3*[1L:3D]: Petek et al., 2005), other studies have found TD prevalence to be unrelated to photoperiod (Onbaşlı et al., 2007; Das and Lacin, 2014). Leg bone quality also appears to benefit from a longer scotophase. Tibial bone ash (Brickett et al., 2007) and breaking strength (Lewis et al., 2009a) have been positively correlated with hours of darkness. Tibial breaking strength was also improved in broilers raised under an intermittent lighting scheme (4L:4D) compared to those maintained under continuous lighting (Yang et al., 2015). The use of stepped lighting is not an effective means of improving broiler leg health. Sherlock et al. (2010) observed that activity levels and GS were unaffected by step changes in lighting intensity (10 and 200 lux, 18L:6D) compared to a control lighting regime (10 lux).

The use of wheat straw as litter has been associated with higher incidences of lameness than wood-shavings (hemp waste was intermediate); regular turning and the addition of fresh straw was not sufficient to improve leg health (Su et al., 2000). There was no effect of litter substrate on TD (Su et al., 2000). GS was lower in pens littered with vermiculite, or a wood-shavings and vermiculite mix, than in wood-shavings alone (Yildiz et al., 2014).

Antibiotics are routinely used in some countries (e.g. USA) during different stages of broiler rearing, although it should be acknowledged that there are wide variations between countries and agricultural antibiotic use in Australia is comparatively low. The receipt of an extra antibiotic treatment by a flock (in addition to that which would be part of normal rearing practice) was associated with a lower GS (Knowles et al., 2008).

Estimated heritabilities of leg problems (TD: 0.21; valgus-varus: 0.72) indicate that genetic selection offers a means by which to reduce non-infectious skeletal disorders, as indicated by the decreased incidence of TD in commercial strains in recent years (Akbaş et al., 2009). Wideman et al. (2014) also identified a sire influence on the susceptibility of broilers to FHN.

B3.4 Contact dermatitis

Appropriate management of litter quality, rather than stocking density, appears to be the most important factor in controlling contact dermatitis; the condition is a serious welfare issue as severe lesions are likely to be painful and provide a gateway for infection.

Contact dermatitis is a skin condition of the feet (FPD or pododermatitis), hocks (hock burn), or breast (breast burn). It can range from skin discolouration and superficial erosions to inflammatory reactions of the subcutaneous tissue and deep necrotic lesions. Breast blisters are thought to develop following prolonged or repeated pressure on the keel bone, so that the sterna bursa becomes swollen and fluid-filled (Nielsen, 2004), forming a lesion upon rupture. Both forms of lesion can be associated with secondary bacterial infections.

B3.4a Foot pad dermatitis (FPD)

FPD is found on the plantar surface of the foot, most commonly the central pad, but it can also be found on the toes.

Scoring FPD

FPD severity may be scored slightly differently in different countries, as reflected by the large variation in scoring systems evident within the literature. Scoring systems range from those concerned with lesion size, including a simple binary score (0: no lesions or a lesion <5 mm in diameter; 1: a lesion >5 mm, Dawkins et al., 2004), and a 4-point scale (0: no lesion;

1: lesion on <25% of the pads; 2: lesion on 25-50% of the pads; 3: lesion on >50% of the pads, (Martrenchar et al., 2002), to more descriptive methods such as the Swedish scoring scale (0: no lesion, slight discolouration of the skin, or healed lesion; 1: mild lesion, superficial discolouration of the skin, and hyperkeratosis; 2: severe lesion, epidermis is affected, blood scabs, haemorrhage, and severe swelling of the skin, (e.g. de Jong et al., 2012b). Other studies have used complex severity scales with as many as seven (Abd El-Wahab et al., 2013) or even 10 categories (Allain et al., 2009). Michel et al. (2012) devised a complex 5-point scale based upon a combination of lesion severity (assessed via macroscopic and histological observations) and lesion size for use in processing plants. The scoring system currently in use on-farm as part of the Welfare Quality® Assessment protocol for poultry comprises a 5-point severity scale developed by Bristol University (e.g. Haslam et al., 2007) and utilises photographic images for reference (Figure B1).

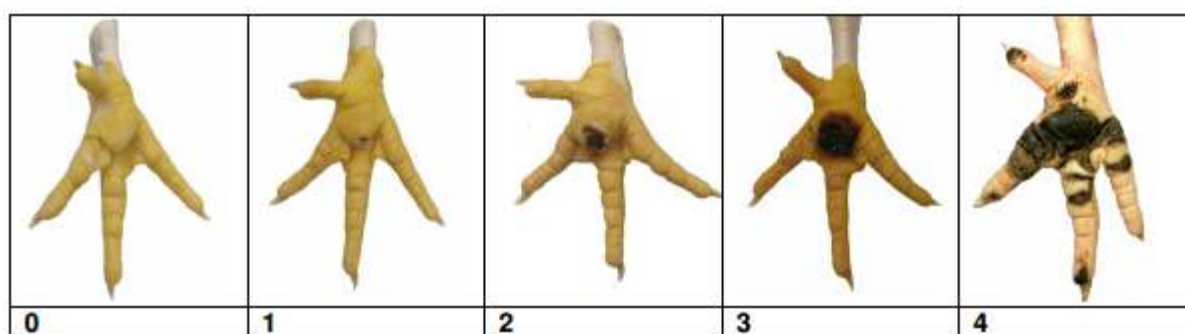


Figure B1: Five point scoring scale (0-4) for categorising foot pad dermatitis lesion severity in broilers (Welfare Quality®, 2009)

To avoid sampling error when FPD lesions are unevenly distributed over a commercial broiler unit de Jong et al. (2012c) recommend the utilisation of at least five different sampling locations within the unit and a sample size of at least 100 birds.

Prevalence, risk factors and control

Great variation in the occurrence of FPD (including severity levels) has been reported, both between flocks and studies: 0-48% (severe, UK: Jones et al., 2005a); 4% (severe, UK: Pagazaurtundua and Warriss, 2006); 0-72% (moderate and severe, UK: Haslam et al., 2007); 0-90% (severe, Italy: Melluzzi et al., 2008a; 2008b); 83% (severe, France: Allain et al., 2009); 75% (any severity, Portugal: Gouveia et al., 2009); 32-100% (any severity, Japan: Hashimoto et al., 2011); 38% (severe, Holland: de Jong et al., 2012b).

FPD generally increases with age in standard fast-growing (Bilgili et al., 2006; Kjaer et al., 2006; Hashimoto et al., 2011; Baeza et al., 2012; Kyvsgaard et al., 2013; Martins et al., 2013; Sarica et al., 2014) and slow-growing breeds (Gouveia et al., 2009; Sarica et al., 2014). Lesions have been observed as early as 7 days post-hatch (Berk, 2009; Hashimoto et al., 2011).

Flock thinning is a partial depopulation, usually of fast-growing broilers, whereby a proportion of the flock is removed to satisfy market demand for lighter birds, and to maintain stocking density within legal limits, (usually) one week prior to the end of production; the remaining birds are kept on until the end of the production cycle. Birds thinned from a flock at a young age (i.e. <38 d) have been observed to have less severe FPD than older depopulated flocks (de Jong et al., 2012b), which fits in with the general expectation that FPD increases with age; however, the presence of a catching team within the house is likely to be very stressful for the uncaught birds, less mobile birds may be walked over and sustain skin lesions, as well as posing a huge biosecurity risk. Birds sent for depopulation at a young age may be seen with high FPD levels; farms that depopulate early generally utilise higher stocking densities and do not thin, which compromises their litter quality (de Jong et al., 2012b). De Jong et al. (2012b) report that FPD severity can decrease with age; the authors hypothesise that this may have been a consequence of flock thinning, since a reduction in stocking density could allow the litter quality to improve. Alternatively, since older birds spend more time resting (e.g. Alvino et al., 2009a) they may reduce the contact-time of their feet with the litter (instead increasing hock and breast contact).

Male birds have been reported to be more susceptible to FPD than females due to their heavier body mass (Bilgili et al., 2006; Nagaraj et al., 2007; Hashimoto et al., 2011; Sarica et al., 2014), but other studies report no differences between the sexes (Gouveia et al., 2009), or that females are more susceptible (Kjaer et al., 2006; Kappell et al., 2012; Schween-Lardner et al., 2013). Similarly varying results have been obtained regarding the relation between FPD and body mass, with observations of a positive correlation between live weight and FPD scores (Sarica et al., 2014), no association (Kjaer et al., 2006), and a negative association (Hashimoto et al., 2013). FPD is generally associated with a loss of

condition/health, perhaps due to a secondary infection associated with lesion presence (Nowaczewski et al., 2011; Kyvsgaard et al., 2013).

Studies comparing FPD prevalence under commercial conditions have highlighted differences in susceptibility between different fast-growing genotypes (Haslam et al., 2007; Yamak et al., 2016); Ross 308 appear to be the most susceptible, despite having a lower body mass (compared to Hubbard Flex: de Jong et al., 2012b; Ross 708: Schwan-Lardner et al., 2013; Hubbard: Skrbic et al., 2015; Cobb: Martins et al., 2016). Fast-growing genotypes have conclusively been shown to demonstrate greater FPD lesion incidence/ severity than slower-growing genotypes (Kjaer et al., 2006; Allain et al., 2009; Sarica et al., 2014; Yamak et al., 2016). Certain production systems appear to be a lot more susceptible to FPD. Flocks with outdoor access generally have higher FPD scores than those housed indoors (Sarica et al., 2014). In the UK, FPD prevalence and lesion severity was seen to be highest in organic systems with outdoor range access, and lowest in indoor Freedom Food systems (Pagazaurtundua and Warriss, 2006). However, there are counter examples. FPD incidence was higher on extensive indoor than traditional free-range farms in Portugal (Gouveia et al., 2009). Both incidence and severity of FPD is higher in solid floor than in wire floor (cage) housing systems (Cengiz et al., 2013; Simsek et al., 2014).

A key property of litter should be the ability to absorb and quickly release moisture (Bilgili et al., 2009). Litter with high absorbance properties often has a small particle size (Cengiz et al., 2011). Broilers reared on chopped straw had a reduced incidence and severity of FPD dermatitis compared to broilers reared on, less-absorbent, unchopped straw (Đukić Stojčić et al., 2016). Wood-shavings appear to be the most appropriate litter bedding type for controlling FPD; flocks reared on wood-shavings or sawdust exhibit less FPD (prevalence and severity) than those reared on chopped straw (Su et al., 2000; Meluzzi et al., 2008a; Berk, 2009; Bilgili et al., 2009; Nowaczewski et al., 2011; Kyvsgaard et al., 2013; Skrbic et al., 2015), rice husks (Petek et al., 2014; Jacob et al., 2016a), grass (Xavier et al., 2010; Garcia et al., 2012), or corncob litter (Xavier et al., 2010). Other litter materials found to have potential for maintaining foot pad health include sand (Simsek et al., 2009a), Pelletinos (chopped straw pressed into pellets at high temperature) (Berk, 2009), and vermiculite (Yildiz et al., 2014). Unfortunately, costs associated with using processed products such as Pelletinos on a commercial level are likely to be prohibitive. The use of recycled paper-based litter, although readily available and highly absorbent, appears to be inappropriate. Broilers reared on a combination of rice hulls and shredded newspaper were found to have greater FPD than broilers housed on rice hulls alone (Santiago et al., 2006), while the use of paper sludge, although not overly detrimental to FPD, increased HB (Villagrà et al., 2011). Jacob et al. (2016a) report a higher prevalence of FPD with a unused rice husk litter than with reused sawdust litter; they hypothesise that this finding may reflect the 'sharpness' of the rice husks damaging the birds feet, but it is more likely to be linked to the water retaining properties of the litter. Surprisingly, reductions in FPD have been reported from reused sawdust litter compared to fresh (Xavier et al., 2010; Jacob et al., 2016a). Since other studies report the opposite, i.e. FPD was increased on re-used litter (Jacob et al., 2016b; Yamak et al., 2016), the ability to successfully re-use litter is likely to depend upon rigorous litter management, effective composting, efficient ventilation and may favour certain (hot, dry) climates. De Oliveira et al. (2015) tested a large range of treatments on (re-used grass) litter, including in-house composting, and the addition of aluminium sulphate, gypsum, quicklime, dolomitic limestone, zeolite, and charcoal, yet found no treatment capable of improving the incidence of FPD compared to control (untreated) litter. The treatment of litter (new straw) with Micropan® (a biological promoter aimed at wastewater treatment) was more successful, this was seen to decrease the litter pH value and significantly improved FPD compared to a control flock (Đukić Stojčić et al., 2016).

The incidence and severity of FPD is often correlated with a deterioration in litter quality, including elevated moisture content and compaction (e.g. Dawkins et al., 2004; Haslam et al., 2006; 2007; Meluzzi et al., 2008b; Allain et al., 2009; Bilgili et al., 2009; Bassler et al., 2013; Kyvsgaard et al., 2013; de Jong et al., 2014; Taira et al., 2014, see section 9.3). Misting systems (Jones et al., 2005a) and increased water consumption (Manning et al., 2007) have both been associated with more FPD, presumably due to a direct impact upon litter moisture. There are exceptions, however; young broilers appear to be more vulnerable to acquiring FPD with or without exposure to poor litter. FPD may occur early in the growing period when litter moisture is low (Hashimoto et al., 2011) and, although early exposure to high-moisture litter was shown to increase FPD incidence and severity (14 days old), no increase was observed following litter wetting at >56 days of age (Cengiz et al., 2011). Improvements in litter quality were also seen to reduce lesion severity in market-age broilers (Cengiz et al., 2011). Wet litter generally has a higher pH value (Abd El-Wahab et al., 2013), since litter pH increases with nitrogen content (from animal waste).

Although a positive relationship between FPD severity and stocking density has often been reported (see B9.1a), with appropriate environmental management it is still possible to maintain good litter quality at high stocking densities. Government surveillance schemes, whereby producers have to reduce their stocking density or correct management deficiencies (e.g. relating to litter quality) if their overall flock score (based on the prevalence and severity of FPD lesions at slaughter) exceeds certain predefined trigger limits, have already proved successful at reducing FPD in Sweden and Denmark (e.g. Kyvsgaard et al., 2013).

Nutritional factors, such as diet composition, nutrient density and feeding programs, impact upon broiler performance and health, and play a significant role in the aetiology of FPD. The incidence and severity of FPD is significantly increased in broilers receiving a vegetable-based protein diet compared to a diet containing vegetable and animal-based proteins (Nagaraj et al., 2007; Cengiz et al., 2013), although this can be rectified via the inclusion of corn-gluten meal (Eichner et

al., 2007). Carvalho et al. (2014) report that sorghum grain has potential for inclusion within broiler diets since it appears to have no effect upon litter quality or FPD incidence when compared to a control (corn and soybean meal) diet. Although FPD has been observed to be more prevalent in broilers fed a high-density than a low-density diet (Bilgili et al., 2006; Nagaraj et al., 2007), the reverse was true for a study by de Jong et al. (2015); they observed more FPD and HB (and higher litter moisture) in broilers fed a low-energy diet.

Cengiz et al. (2012) report that feed supplementation with dietary enzymes (including xylanase, protease, and amylase) to target the non-soluble polysaccharide component of feed (thought to be linked to contact dermatitis) had no effect on either FPD incidence or severity; however, when combined with a direct-fed microbial (*Bacillus*) dietary enzymes have been shown to improve production parameters, litter quality and reduce FPD under commercial conditions (Dersjant-Li et al., 2015). Inclusion of a fatty acid (Aromabiotic) dietary supplement (Khosravinia, 2015), and increasing dietary fat content (Fuhrmann and Kamphues, 2016), vitamin D3 (Sun et al., 2013), and zinc and biotin (Abd El-Wahab et al., 2013) are all associated with lower FPD scores. The provision of reduced levels of 2-hydroxy-4-(methylthio) butanoic acid chelated trace minerals (either Zn alone or as a combination of Zn, Cu, and Mn) into broiler diets as an alternative to industry levels of inorganic trace minerals have also been found to significantly reduce FPD in fast-grow breeds (Zhao et al., 2010; Manangi et al., 2012; Da Costa et al., 2016). Antibiotics are often used to improve broiler gut health and indirectly improve litter quality. Less severe FPD has been observed on farms using antibiotics, potentially reflecting better flock health (de Jong et al., 2012b). With a recent push to reduce antibiotic usage in all livestock there has been a surge of research into the application of prebiotics; some studies have already demonstrated prebiotics to be more effective at maintaining broiler intestinal health than an antibiotic treatment (e.g. Al-Baadani et al., 2016).

A long dimly-lit lighting regime appears to be a risk factor for FPD. A negative correlation between light intensity (1-40 lux) and ulcerative FPD at 5 weeks has been seen in intensively housed broilers (Deep et al., 2010). Very low light intensities (0.5-5 lux) have been associated with increased FPD lesions in some studies (Deep et al., 2010; 2013; Senaratna et al., 2016), but not in others (Blatchford et al., 2009). FPD scores have been positively correlated with day length (Bassler et al., 2013; Schwean-Lardner et al., 2013), which suggests some beneficial effects of a long scotoperiod. Huth and Archer (2015a) report that light-bulb type may also be important, as light provided by light-emitting diode (LED) bulbs (particularly a 'Once Innovations' bulb) appeared to be linked with improved FPD and HB scores when compared with a compact fluorescent.

'Hatchery' had been identified as a risk factor for FPD, indicating that chick quality may be related to FPD susceptibility (de Jong et al., 2012b); however, when the foot health of broilers (same parent stock) obtained from two different hatcheries were compared no effect of hatch location was evident (de Jong et al., 2015). A rise in incubation temperature (37.2-39.2 °C) over the 21 days negatively influenced foot pad skin development (decreased papillae width, dermis height and area) at hatch compared to a control incubation treatment (37.8 °C); weaker foot pad skin and papillae resulting from fluctuating incubation temperatures may, therefore, increase FPD risk (Da Costa et al., 2016). Egg weight does not appear to influence FPD (Kjaer et al., 2006). Breeding programmes offer a means by which flock susceptibility to FPD can be selected against and reduced (see B3.4b).

B3.4b Hockburn (HB)

HB is a contact dermatitis found on the skin of the caudal (back) part of the hock joint, starting as a dark skin discolouration.

Scoring HB

Several hock-scoring systems have been described. These range from the simple, including a three point scale to classify lesions according to foot pad coverage (0: no discolouration or lesions; 1: <10% hock with lesion; 2: >10% hock with lesion, Dawkins et al., 2004), to the complex; Allain et al. (2009) developed a 7-point HB severity scale based on lesion severity. The scoring system currently in use on-farm as part of the Welfare Quality® Assessment protocol for poultry comprises a 5-point severity scale developed by Bristol University (e.g. Haslam et al., 2007) and utilises photographic images for reference (Figure B2).

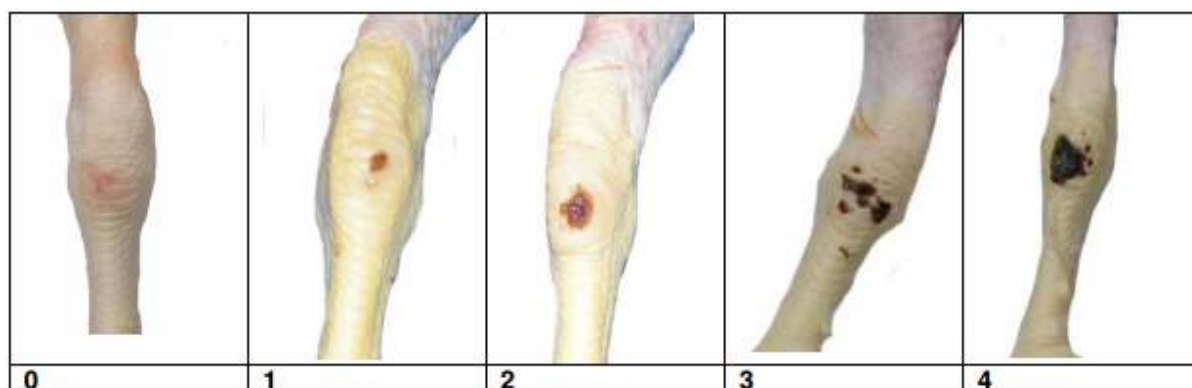


Figure B2: Five point scoring scale (0-4) for categorising hock burn lesion severity in broilers (Welfare Quality®, 2009)

Prevalence, risk factors and control

Although HB develops more slowly than FPD (Skrbic et al., 2015), and HB is observed less frequently (Haslam et al., 2007; Allain et al., 2009), both are often associated (Meluzzi et al., 2008b; Allain et al., 2009; Bassler et al., 2013). As with FPD, a substantial variation in HB prevalence (including severity levels) between studies and individual flocks has been reported: 1.5% (severe, UK: Dawkins et al., 2004); 0-33% (moderate or severe, UK: Haslam et al., 2007); 3-87% (any, Italy: Melluzzi et al., 2008a; 2008b), 59% (any, France: Allain et al., 2009), 12% (any, UK: Hepworth et al., 2011).

HB incidence is positively correlated with age (Kjaer et al., 2006; Haslam et al., 2007), sex (heavy males are more at risk (Oviedo-Rondón et al., 2009a; Henriksen et al., 2016), and body mass (Sørensen et al., 2000; Broom and Reefmann, 2005; Kjaer et al., 2006; Haslam et al., 2007; Hepworth et al., 2010; Henriksen et al., 2016). Hepworth et al. (2010) identified that body mass at two weeks of age was a predictor of flocks at risk of developing HB prior to slaughter. Genotype differences in HB incidence have been observed between standard (fast-growing) breeds (Haslam et al., 2007; Skrbic et al., 2015), while slow-growing breeds appear to be less susceptible (Kjaer et al., 2006). Lameness is positively associated with HB (Sørensen et al., 2000; Haslam et al., 2007); presumably as broilers age, become heavier (and experience deteriorations in leg health), they spend more time lying down, increasing contact-time with the litter.

Ahmad et al. (2013) report a reduction in HB under an intermittent feeding regime (1 h feed; 3 h off) and a feed withdrawal regime (09:00-17:00 h), compared to *ad libitum* feeding; however, these findings were associated with weight gain reductions that were unlikely to be acceptable under commercial production. The provision of an increased percentage of dietary wheat has been linked with reduced HB (Haslam et al., 2007).

Rearing system may influence the risk of developing HB, as 'organic' chickens (observed as carcasses within supermarkets) were seen to have half as many lesions as conventionally reared broilers (Broom and Reefmann, 2005). Jones et al. (2005a) identified that high RH (after week 1 of the production cycle), and the provision of more drinkers per unit area, led to higher litter moisture and a greater incidence of HB. An increased risk of HB has also been associated with increased water consumption towards the end of the grow-out period (Hepworth et al., 2010); litter quality may be reduced directly via increased spillage and indirectly via increased excretion. These findings are supported by many studies that report HB to be higher in flocks maintained upon wet degraded litter (Dawkins et al., 2004; Meluzzi et al., 2008b; Allain et al., 2009; Bassler et al., 2013; de Jong et al., 2014). The use of automatic water meters is associated with a decreased HB risk (Hepworth et al., 2010); the authors hypothesise that an ability to monitor and control water intake may facilitate better stockmanship and improve litter management. As with FPD, HB lesion incidence is also higher during colder months (Meluzzi et al., 2008b; Hepworth et al., 2010), this is again likely to reflect inadequacies in ventilation and litter quality. Lower HB scores were observed at the end of the grow-out period in broilers reared on wood-shavings than paper sludge (Villagrà et al., 2011) or chopped straw (Skrbic et al., 2015). The incidence of HB in broilers reared on reused litter has also been reported to be higher than in those reared on new litter (Jacob et al., 2016a). The provision of a decent scotoperiod appears important in limiting HB; HB scores have been positively correlated with day length (Bassler et al., 2013). The majority of studies report a positive relationship with stocking density, especially at the end of the grow-out period (Arnould and Faure, 2004; Hepworth et al., 2010; Ventura et al., 2010; Sun et al., 2013; Zhao et al., 2013).

An effect of hatchery on HB has been identified (Haslam et al., 2007). Broilers incubated at higher temperatures (39-40 °C) had a greater severity of HB (Ipek and Sozcu, 2016). Although egg weight was not seen to influence HB (Kjaer et al., 2006), low hatching weight appeared to reduce the risk of later developing HB. Broilers originating from young parent breeders, particularly those with low hatching weight, had lower HB scores compared to broilers originating from older parents; however, increasing brooding temperature (37 vs 33 °C) during the first week post-hatch, increased activity, delayed body weight gain, and reduced the incidence of HB at 5 weeks in both high and low hatching weight chicks

(Henriksen et al., 2016). The identification of significant between-line differences in the prevalence of (severe) FPD and HB indicates that the susceptibility to developing these pathologies has a genetic basis. This genetic variation has been verified by heritability estimates as follows: HB: 0.08 (Kjaer et al., 2006); 0.17 (Arkas et al., 2009); 0.10 (Ask, 2010); FPD: 0.3 (Kjaer et al., 2006); 0.34 (Akbas et al., 2009); 0.08 and 0.21 (Ask, 2010); 0.78-0.82 (Kappell et al., 2012). The existence of non-significant genetic correlations between FPD, HB and body weight suggest that a genetic improvement in both FPD and HB could be achieved simultaneously while enabling further improvements in production parameters (Kjaer et al., 2006; Ask, 2010).

B3.4c Breastburn and breast blisters

Breastburn is a contact dermatitis found on the skin overlying the sternum; it is much less frequently seen than FPD or HB and, as a consequence, remains comparatively understudied. Breast blisters (or keel cysts) are an enlargement of the sterna bursa, which is a naturally occurring structure in chickens. The overlaying skin becomes softened and sometimes discoloured; it may show as a raised fluid-filled blister or it may be broken, infected and 'sticky' (Welfare Quality®, 2009).

Scoring and prevalence

The presence of breastburn and severe HB has been positively correlated (Allain et al., 2009). Prevalence has been reported as: 0-0.12% (UK: Haslam et al., 2007), 16% (France: Allain et al., 2009), and 18% (Portugal: Gouveia et al., 2009); all studies employed a binary scoring system (present/absent). Studies on breast blisters have employed a binary scoring system based upon blister size (0: not present or blister measuring <0.5 cm²; 1: blister measuring ≥0.5 cm², Allain et al., 2009) and a 3-point severity scale (0: no blisters; 1: small and colourless blisters; 2: large or dark coloured blisters, Nielsen, 2004). The scoring system currently in use on-farm as part of the Welfare Quality® Assessment protocol for poultry comprises a binary scale to record breast blister presence or absence (0: no evidence of breast blister; 1: evidence of breast blister) and utilises photographic images for reference (Figure B3). The only recent study to report breast blister prevalence observed a mean of 4% in France (Allain et al., 2009); however, substantial inter-flock variation was evident (0->10%). This study observed a negative correlation to exist between: (i) the presence of breast blisters and deep HB, and (ii) the presence of breast blisters and deep FPD (Allain et al., 2009), presumably reflecting the body parts most often in contact with the floor.

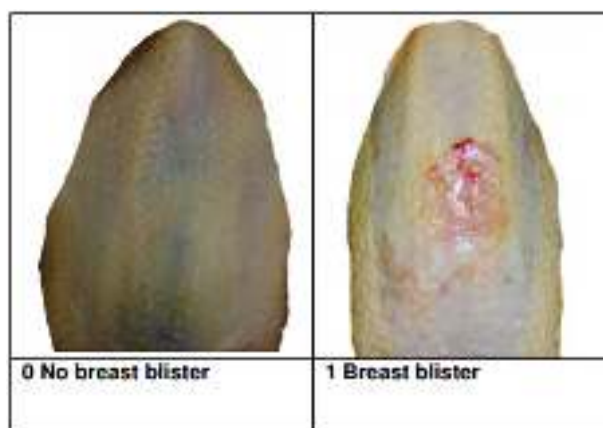


Figure B3: Two point binary scale (0-1) for recording the presence or absence of breast blisters in broilers (Welfare Quality®, 2009)

Risk factors

Male broilers have been found to be more predisposed to breastburn than females (Gouveia et al., 2009). In a fast-growing breed Zhao et al. (2009) observed no sex-related difference in breast blister incidence; however, slow-grow males housed in an extensive system were seen to have a higher incidence of breast blisters than females (Nielsen, 2004). A slower-growing genotype was reported as having a greater prevalence of breast blisters than a fast-growing genotype (Allain et al., 2009). When two slow-grow strains were compared Labresse broilers were more likely to develop breast blisters than Hubbard ISA i657 broilers (Nielsen, 2004).

Litter moisture was positively correlated to breastburn incidence between 21-36 days in a recent study (de Jong et al., 2014), whereas an earlier study observed no link between the percentage of birds with breastburn and litter quality, or average ammonia concentrations (Haslam et al., 2006). This study also failed to ascertain an association between stocking density and breastburn (Haslam et al., 2006). The occurrence of breast blisters has been positively correlated with stocking density (Allain et al., 2009; Zhao et al., 2009). There is very little information on which litter materials are risk

factors, if any, but Santiago et al. (2006) reported the use of rice hulls alone, or with recycled paper products, had no influence on breast blister score. In cage-reared broilers floor-type appears to be important in breast blister formation; the occurrence of breast blisters was significantly higher in cages with wire netting than in those with plastic or bamboo slats (Zhao et al., 2009). A positive association between perch access and severe breast blisters was reported for a strain of slow-growing broiler (Nielsen, 2004); however, as the birds didn't use the perches very much the association is unlikely to be direct.

B3.4d Welfare impact of dermatitis

Although there is no evidence for a relationship between contact dermatitis and mortality (de Jong et al., 2012b), the lesions can become infected with a variety of bacteria. In broilers, both FPD and HB are associated with an increased incidence and severity of *Campylobacter* infection (Bull et al., 2008; Rushton et al., 2009). Hepworth et al. (2011) report HB to be a useful indicator of flock health; HB was positively associated with the percentage of birds with septicaemia and fever, detected post-mortem. De Jong et al. (2014) observed reductions in production parameters (including body weight) and walking ability (increased GS) in broilers reared on wet litter. As FPD was also increased on wet litter the authors hypothesise that birds with deep or infected lesions may have experienced pain and consequently fed and drunk less due to inappetence (de Jong et al., 2014). Sherlock et al. (2012) compared global hepatic gene expression in control birds and in those with experimentally induced FPD and HB lesions and report evidence for the inflammatory reaction to impact upon key pathways linked with growth, metabolism and energy utilisation. The authors hypothesise that pain may be the underlying trigger for the up-regulation of genes linked to a pro-inflammatory response and energy metabolism (Sherlock et al., 2012). Further evidence for FPD having a pain component is provided by Hothersall et al. (2016); LTL performance was negatively associated with FPD score, and standing ability was improved following treatment with two different NSAIDs.

B3.5 Parasitic infections

Coccidiosis (protozoa) is a major cause of gut disease in broilers, usually managed by the inclusion of coccidiostats within the feed; however, mites and worms are less of a problem for indoor reared birds due to short broiler production cycles.

B3.5a Mites

Although common within laying hen facilities (see LH3.11a), arthropod parasites such as red mite (*Dermanyssus gallinae*) and the northern fowl mite (*Ornithonyssus sylviarum*), tend to cause fewer problems in broiler production (Sparangano et al., 2009), possibly due to short production cycles and extensive, repeated, house cleaning and acaricide treatments that occur between flocks. Systems which allow birds outdoors, grow the birds for longer, or have older wooden housing will be more at risk, but very little data exists regarding mite prevalence.

B3.5b Coccidiosis

Coccidiosis, caused by the protozoan parasite *Eimeria*, is a major disease of broilers. Clinical disease is associated with bloody droppings and increased mortality; however, infection is usually maintained at a sub-clinical level, whereby intestinal lesions are associated with feed malabsorption and impaired growth rates. The general drive to reduce the use of anti-coccidial drugs was covered in LH3.11b and there are additional problems of resistance to such drugs in the broiler industry. For example, Chapman and Jeffers (2015) found that partial resistance to in-feed coccidiostat (Sacox), measured by oocyst production developed over 5 successive flocks. There has been some success with the application of prebiotics and probiotics as alternatives to anti-coccidial feed-delivered drugs and expensive live vaccines. Lee and Chen (2007) observed a commercial probiotic to effectively enhance the resistance of broilers to infection and partially protect against the depression in flock performance. Ritzi et al. (2014) found that a probiotic treatment (containing *Bacillus* and other probiotics, but source not given) yielded similar levels of protection to a coccidiosis challenge when compared to in-feed treatment (with Sacox). Bozkurt et al. (2014) found that probiotics (Primalac, Start Labs, Missouri), pre-biotics (Bio-Mos, Alltech, Kentucky) and multienzyme (Karyzyme 8601, Kartal Chemistry, Turkey) were all effective at improving weight gain, feed conversion ratios and intestinal lesions following an *Eimeria* challenge. In the latter study, the three alternative control methods were as effective as in-feed treatment (Sacox 120, Bulgaria). However, it was unknown how much previous flocks in these systems had been treated and whether there may have been resistance. Coccidiosis is associated with wet litter, highlighting a further need to control this disease (Hermans et al., 2006). With growing pressure to reduce the use of anti-coccidial drugs, vaccination is likely to become an increasingly important strategy in the broiler sector (see also LH3.11b).

B3.5c Worms

Ascaridia, as well as *Capillaria* spp. (nematodes), can cause production losses in broiler breeders, but are not generally a problem in broilers due to their short production cycle.

B3.6 Infectious disease

Campylobacter and E. coli cause health problems in broilers as well as humans; high stocking density increases risk of infectious disease.

Housing broilers under high stocking density appears to increase susceptibility to infectious disease (see B9.1a). Necrotic enteritis (due to an acute *Clostridium* infection) is a common bacterial disease, characterised by severe necrosis of the intestinal mucosa (see B2.4). *Campylobacter jejuni* is the leading cause of bacterial food-borne infection, chicken meat being the main source. *C. jejuni* is generally considered a harmless commensal in broilers; however, Humphrey et al. (2014) observed that different broiler breeds demonstrate different immune responses to *Campylobacter* infection. Some breeds demonstrate an acute innate immune response and remain healthy (sub-clinical infection), while another breed underwent a prolonged inflammatory response, had damage to the gut mucosa, and diarrhoea (clinical infection) (Humphrey et al., 2014). *Campylobacter* disease has welfare implications for broilers in commercial production where infection is a persistent problem. Bull et al. (2008) report that the presence of *Campylobacter* in housed broilers was associated with indicators of poor flock health, such as increased rates of infectious disease and contact dermatitis; improving health and welfare may, therefore, also reduce *Campylobacter*. Acute stressors in poultry production systems, including 24 hour feed withdrawal and exposure to high (30 °C) transient temperatures, have been shown to alter epithelial structure and intestinal microbiota, which potentially increases bird susceptibility to colonisation by *Salmonella enteritidis* (Burkholder et al., 2008). Kemmett et al. (2014) observed that *E. coli* also makes a significant contribution to young chick mortality; approximately 70% of dead chicks (collected up until 72 h following placement) displayed signs of colibacillosis. The authors hypothesise that broiler breeder reproductive tract infections, poor egg hygiene and transportation all contribute to early *E. coli* colonisation of the neonatal gut (Kemmett et al., 2014).

B3.7 Aggression

Aggression is more common in slow-grow broiler breeds and is more likely to be observed in open areas, particularly on the range.

Aggression has been reported to vary with age, peaking in the second to third week, and then decreasing again as broilers get older, heavier and less active (Cornetto et al., 2002; Pettit-Riley et al., 2002). Birds from a slow-growing strain (JA 657 Hubbard ISA) demonstrated more aggression than birds from a fast-growing line (HI-Y Hubbard ISA) (Bokkers and Koene, 2003a) and, when housed in small experimental flocks, slow-growing (Delaware) birds performed more aggression outside on the range than inside the house (Fanatico et al., 2016). Inside the house the majority of agonistic interactions generally occur in the centre of the floor space, with least aggression seen along the external walls, where broilers prefer to lie and rest (Cornetto et al., 2002; Pettit-Riley et al., 2002). Aggression has been linked with larger flock size in small experimental studies (e.g. Sosnowka-Czajka et al., 2007). In a study of meal-fed broilers a reduction in agonistic behaviour during the feeding period was achieved by increasing the feeder space from 2.4 to 3.6 cm/bird (Olukosi et al., 2002).

B4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

B4.1 Influence of selection

Selection for growth impedes broiler activity from 3 weeks and limits the range of behaviours which they can perform; Slow-growing breeds do not demonstrate mobility or behavioural restrictions to the same extent as fast growing breeds.

Compared to other breeds of *Gallus gallus domesticus*, broiler chickens have very different time-budgets. In a study by Weeks et al. (2000) non-lame broilers of a fast-grow breed (39–49 days old) spent approximately 76% of their time lying down. The time budgets of fast- and slow-growing broilers are also different. Slow-growing broilers perform more perching, walking and ground scratching, while fast growing broilers perform more sitting, eating and drinking; both perform similar proportions of resting, preening, stretching, ground pecking and dust bathing (Bokkers and Koene, 2003a). Resting may have a genetic, rather than a morphological, background since the fast-growing broilers weighed twice as much as the slow-growing broilers (Bokkers and Koene, 2003a). Fast-growing broilers demonstrate lower activity levels from week one onwards, while slow-growing broilers maintain higher activity levels throughout the production period (Reiter and Bessei, 2009). Differences in behavioural time budgets have also been reported in young chicks; fast-grow breeds feed more and walk less (Bizeray et al., 2000). Correlations between early chick activity and subsequent active behaviour in a fast-grow breed were observed by Bizeray et al. (2000), but not by Nielsen (2012). This suggests that, at least in some strains, an 'active' flock (potentially with fewer leg problems) could be achieved via the selection of mobile broiler chicks (Bizeray et al., 2000).

Although it is possible to keep fast-growing broilers to 12 weeks on a qualitatively restricted diet, several behaviours are performed less with age, presumably due to the physical consequences of increased weight associated with a prolonged rearing period; walking, perching and ground scratching all decreased (Bokkers and Koene, 2003a). The authors hypothesise that fast-grow broilers are still motivated to walk but become frustrated with their immobility, since an increase

in preening was also observed. It is generally accepted that displacement preening is associated with frustration (Duncan and Wood-Gush, 1972, cited by Bokkers and Koene, 2003a).

B4.2 Inactivity: morphology or absence of motivation?

It is likely that heavy broilers are still motivated to perform locomotory behaviour even when physically unable - this may lead to frustration and low welfare.

The morphology of modern broiler breeds (high body mass and reduced leg health) physically limits their ability to perform certain behaviours even if they are motivated to do so. The distinction between physical ability and motivation is highly relevant to welfare since an unfulfilled motivation may be associated with frustration, stress and suffering. The absence of motivation, e.g. for activity, would be less of a welfare concern.

There is evidence that broilers are motivated to walk to obtain food, but that their high body mass is a cause of low activity. Fast-growing broilers were sometimes unable to complete a physical task to obtain food and demonstrated behaviours indicative of frustration (Bokkers and Koene, 2004). Distance walked in a runway test to access a feed reward was shown to be affected by both physical ability and motivation. After controlling for body mass, it was seen that both, (a) a longer feed deprivation period and, (b) a shorter feed reward access time, stimulated birds to walk further (Bokkers et al., 2007). The actual distance walked was greater for lighter birds but the motivation to do so was similar for birds of all weights (Bokkers et al., 2007). In addition, Rutten et al. (2002) showed that the use of a suspension device to experimentally reduce load-bearing on broiler legs (alleviate body mass) enhanced voluntary locomotor activity by 35%.

Fast-growing broilers appear to spontaneously limit their physical effort from as early as 3 weeks, even when reared at low density (2 broilers/m²); nutritionally satisfied non-lame broilers tend to congregate (mainly lying) near drinkers and feeders or peripheral walls, making little use of the more open areas of floor space for activities such as walking and ground scratching (Cornetto and Estevez, 2001a; 2001b; Arnould and Faure, 2004). This indicates that the rearing environment for modern broiler production, usually large, predominantly barren, floor areas, is not sufficient to stimulate locomotor activity. Some success in improving the overall use of the floor space has been achieved via the provision of barrier perches and vertical mesh panels (see B5.3 and B5.4). These studies suggest that impaired physical ability is a dominant restrictive factor for walking in older heavier birds, while the motivation to move remains a key factor for locomotion in younger lighter birds.

B4.3 Innate hunger

Broilers are unlikely to experience constant hunger.

Based upon evidence indicating that broilers eat to their maximal physical capacity, Bokkers and Koene (2003b) hypothesised that the food intake control mechanisms of intensively selected broilers have been altered (due to the high demands of fast growth rates), which could leave them feeling constantly hungry, a major welfare issue. They proposed that a positive correlation between the pre-feeding interval and the feeding bout duration indicates that broilers are unable to “switch-off” feeding through normal satiety mechanisms. Instead Bokkers and Koene (2003b) proposed that broilers stop feeding only when physically unable to ingest further feed. However, although differences in the characteristics of short-term feeding behaviour were subsequently identified (fast-growing breeds have longer and larger meals than slow growing breeds), Howie et al. (2009) could find no evidence for constant hunger, although their data are consistent with the idea that selection may have interfered with the “switch off” satiety mechanism. There is a need for further work on potential hunger in *ad libitum* fed broilers.

B4.4 Behavioural need to perch

In fast-growing broilers perch use is limited by body mass; slow-grow breeds have better leg health and perch more frequently.

Perching may be beneficial in alleviating leg problems and enhancing mobility in broilers, as it stimulates diversification of locomotion (Norrington et al., 2016). Generally slow-growing broilers have better leg health and use perches more frequently than fast growing broilers (Bokkers and Koene, 2003a); however, perching behaviour has been shown to be highly variable even between slow-growing breeds (Nielsen, 2004; Lee and Chen, 2007; Rodriguez-Aurrekoetxea et al., 2015). Nielson (2004) observed one slow-grow breed to start perching at 2 weeks of age, while another started a week later. The use of perches by fast-growing broilers generally increases with age, peaking between 4–5 weeks and dwindling thereafter (LeVan et al., 2000; Pettit-Riley and Estevez, 2001; Bizeray et al., 2002b; Bokkers and Koene, 2003a; Ventura et al., 2012; Hongchao et al., 2013; Bailie and O’Connell, 2015), likely due to increased body mass. No studies have been conducted to distinguish broiler motivation to seek elevated areas and motivation to grasp a pole with the foot. The use of hay bales (Ohara et al., 2015) and platform use (Norrington et al., 2016) also decreases with age, towards the end of the grow-out period. Females generally use perches and bales at a higher frequency than males (Estevez et al., 2002; Ohara et al., 2015). The effects of varying perch characteristics are presented in B5.3.

Several studies have revealed that time of day influences perching behaviour, although different patterns of behaviour have been reported according to the type of elevated structure. Perches are generally used nocturnally, before 08:30 h and after 20:30 h (LeVan et al., 2000; Nielson, 2004), while platforms are used more during the day, implying a non-roosting function (Norring et al., 2016). Not all broiler flocks roost. Commercial egg producers often utilise an artificial dusk to encourage laying hens to perch before complete darkness; however, the addition of a 10 minute artificial dusk at the end of the lighting period was not found to prompt perching behaviour in broilers (Martrenchar et al., 2000).

B5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

Commercial broilers are typically reared in low complexity environments, under low-level lighting, with minimal stimulation. Many studies have attempted to utilise environmental enrichment and to improve broiler welfare by encouraging activity and the expanse of the behavioural repertoire, with varying success.

B5.1 System type

Fast-growing breeds, selected for productive performance, do not perform well under extended production and should not be used in extensive systems. Cage housing triggers fear and stress in broilers.

The vast majority of broilers are kept in indoor floor systems. If a free-range system is used, then the genotype must be carefully selected. The use of fast-growing genotypes in organic broiler poultry production can create severe problems for animal welfare. Ross broilers (208 and 308 strains) have a growth rate unsuited for an extended (12 week) production cycle in a free-range system and demonstrate a poor welfare status after 70 days including poor plumage, a high culling and mortality rate, impaired mobility, joint inflammation, pectoral myopathies, severe FPD, breast blisters, and high fearfulness (Nielsen et al., 2003b; Dal Bosco et al., 2014; Castellini et al., 2016). In addition, they demonstrate high inactivity and make low use of the outdoor space (Nielsen et al., 2003b; Castellini et al., 2016). Of two medium-grow breeds a Naked Neck genotype appeared to be better adapted to an organic environment than a Kabir genotype (FPD: 20 vs 60%; breast blisters: 0 vs 20%), although productive yields were slightly lower (Dal Bosco et al., 2014). The occurrence of feather-pecking and cannibalism by a medium-grow experimental Labresse-cross housed in a free-range system was a very unusual observation for any broiler flock, let alone one housed extensively (Nielsen et al., 2003b); the authors raise doubt on this particular genotype's suitability for meat-type poultry production under any system.

Certain aspects of welfare (for suitable strains) appear to be better on organic and/or free-range farms than conventional farms, most notably the opportunity for expression of natural behaviours (see B6.2). Although higher FPD levels have been associated with outdoor access (see B3.4), Tuytens et al. (2008) observed organically reared broilers to have better leg health (less HB and longer LTL) and lower fluctuating asymmetry measures than conventional flocks. Lower HB in organic broilers has also been reported by Broom and Reefmann (2005). Although *Campylobacter* prevalence was similar, levels of alpha-1-acid glycoprotein, an acute phase protein indicative of immunological challenge, was elevated in organic flocks (Tuytens et al., 2008).

Very few recent studies have been conducted on the welfare of cage-housed broilers, as this is not a common housing system. Evidence for reduced welfare in cage batteries includes higher blood glucose (Skomorucha and Muchacka, 2007; Özhan et al., 2016) and increased fearfulness (Skomorucha and Muchacka, 2007). Broilers housed in small groups (n=37) on litter were seen to perform more aggressive behaviour, preening and wing-flapping behaviour than cage-housed broilers, and they had higher final live-weights (Fortomaris et al., 2007). Cage floor-type appears to be important in breast blister formation; the occurrence of breast blisters was significantly higher in cages with wire netting than in those with plastic or bamboo slats (Zhao et al., 2009). Both the incidence and severity of FPD has been found to be higher in solid floor than in wire floor (cage) housing systems (Cengiz et al., 2013; Simsek et al., 2014), although this could potentially have been alleviated with improved litter quality.

B5.2 Litter substrate

Although sand is a 'preferred' substrate for performing dust-bathing and comfort behaviours, wood-shavings are a suitable alternative litter-type.

When given a choice between sand and wood-shavings as litter, broilers increasingly performed the majority of their total behavioural time budget on sand (including preening and dust-bathing) (Shields et al., 2005; Toghyani et al., 2010), but if only one litter-type was provided (sand or wood-shavings) they performed all behaviours on either material with similar frequency (Shields et al., 2005).

B5.3 Use of perches and elevated structures

Perch provision does not appear to be particularly useful for broilers given their limited use. Straw bales or low wooden barriers increase activity, encourage perching behaviour and provide additional resting areas and 'cover'; straw bales provide additional pecking enrichment, are readily available and easily disposed of at the end of a cycle.

Broilers frequently perch on straw bales when they are provided (Kells et al., 2001; Bailie et al., 2013; Ohara et al., 2015); however, some experimental studies on actual perch use indicate that these are only used to a modest degree, by 1-7% of birds on average (LeVan et al., 2000; Su et al., 2000; Pettit-Riley and Estevez, 2001; Hongchao et al., 2013). Perch design is obviously very important. The majority of these studies created low (8.5 cm high) perches out of PVC piping, whereas slightly higher (15 cm) horizontal wooden designs appear to be preferred; fast-grow broilers have been reported to perch for as much as 10-25% of their time on the latter (Bizeray et al., 2002b; Bokkers and Koene, 2003a; Ventura et al., 2012; Bailie and O'Connell, 2015). Perch diameter is usually 4-5 cm in these studies. Perch height appears to be critical, even for extensive breeds; Rodriguez-Aurrekoetxea et al. (2015) observed slow-grow broilers to only spend 0-3% of their time on a horizontal 25 cm high perch. Broilers have been observed to use low perches (10 cm) more than high perches (30 cm) at 5 weeks (Norrington et al., 2016), although this is likely to reflect physical challenge rather than a lack of motivation to access an elevated position. Broilers tend to use horizontal perches the most, with roosting decreasing as the perch inclination increased from 10° to 20° (LeVan et al., 2000; Pettit-Riley and Estevez, 2001). Perch positioning appears to be less important; although LeVan et al. (2000) reported that perches located in the centre of the pen were used more than those located near a wall, the opposite effect was observed in a later study (Pettit-Riley and Estevez, 2001). Norring et al. (2016) observed elevated plastic platforms (accessed by ramps) to be much more frequently used than wooden perches in a commercial setting. Use of a high platform may indicate that broilers were motivated to achieve elevation from the floor level and/or to escape from flock mates. In warmer climates perch use could be improved by water-cooling. Estevez et al. (2002) observed 8% of birds to perch on cooled perches, whilst 4% perched on non-cooled perches, during the last week of rear.

Broilers provided with hay bales are generally more active than control birds (Kells et al., 2001; Bailie et al., 2013; Ohara et al., 2015); however, there does appear to be a maximum activity level. Bailie et al. (2014) observed that increasing the number of bales had no additional effect upon activity. Several studies have failed to show an increase in general locomotor activity following the provision of elevated structures (Bizeray et al., 2002b; Rodriguez-Aurrekoetxea et al., 2015; Norring et al., 2016), while others have reported birds to be less active (Hongchao et al., 2013; Bailie and O'Connell, 2015). The provision of wooden barrier perches stimulated some broilers to perch, in preference to lying on the litter (Bizeray et al., 2002b; Ventura et al., 2012) and, due to changes in the way that the birds used the available space, they also lowered aggression and disturbances (of resting individuals) compared to control environments (Ventura et al., 2012). Interestingly, Pettit-Riley et al. (2002) observed that horizontal or angled perch provision was associated with higher levels of aggression than observed in a non-enriched control environment, the opposite effect than anticipated; however, most aggressive interactions occurred in the open areas of the pen rather than near the perches themselves. Rodriguez-Aurrekoetxea et al. (2014) reported that the provision of perches led to more birds using the central indoor area of the house, resulting in a more homogeneous use of the space.

B5.4 Use of vertical panels

Vertical mesh-covered panels appear to have the potential to improve broiler welfare by decreasing aggression (reducing visual contact) and disturbances (increasing resting), and promoting a more even distribution of birds throughout the pen space.

Uneven use of space can have deleterious effects on health and comfort, particularly when birds are kept at high densities. Several studies have attempted to increase environmental complexity via the provision of barrier perches and 'cover' (vertical mesh panels) to increase locomotory behaviour in the central floor area, and produce a more homogeneous distribution of birds within the overall floor space (Cornetto and Estevez, 2001b; Ventura et al., 2012; Rodriguez-Aurrekoetxea et al., 2014; 2015). Disturbances by conspecifics are frequently observed in groups of chickens reared in large groups and at a high density (Arnould and Faure, 2004). Jostling for space near the wall causes high frequencies of disturbances to those already resting there, more so than in any other part of the pen; these disturbances are more prevalent in larger experimental group sizes and are associated with mild skin lesions (Cornetto et al., 2002). The provision of vertical mesh panels was not found to reduce aggressive interactions, but they did provide additional resting places and halved the occurrence of wall disturbances (Cornetto et al., 2002). Cornetto and Estevez (2001a) observed that resting time was higher in pens enriched with panels; in a control treatment resting and preening were performed the least in the pen centre, yet under panel provision both were seen to increase.

B5.5 Use of other enrichment devices

Increasing environmental complexity via the provision of (alternating) toys from placement appears to make broilers more adaptable to novelty and better able to cope with fear-inducing stimuli; string and moving lights do not appear to provide useful 'enrichment'.

Although the provision of string devices has been a successful approach to reduce feather pecking in both experimental and commercially raised layers (LH3.5), the benefits of hanging string within broiler sheds are less clear. Bailie and O'Connell (2015) report lower GS in broilers provided with string and frequent string manipulation (especially mid-production cycle); however, no improvement in leg health was indicated by LTL measures, and string provision was associated with lower activity levels towards the end of rear (compared to birds without enrichment). Other studies report

broilers to demonstrate little interest in string when it was provided in either an experimental (Arnould et al., 2004) or commercial (Hocking and Jones, 2006) setting.

The provision of sand trays can attract broilers into floor areas otherwise rarely used and promote increased foraging behaviour, but has no effect upon locomotor activity or tarsal deformities (Arnould et al., 2004). Although dust-bathing in broilers is rarely observed, they will perform this behaviour if given access to a suitable substrate, such as sand (Bokkers and Koene, 2003a; Shields et al., 2004). Broilers were observed to perform more dust-bathing in sand, and spent a greater proportion of their total time located within an area containing sand, than in areas containing rice hulls, paper, or wood-shavings; no dust-bathing was seen to occur in rice hulls (Shields et al., 2004). Dust-bathing has been reported in broilers as old as 12 weeks (Bokkers and Koene, 2003a), demonstrating that this natural behaviour is still possible despite a heavy body mass. Under experimental conditions broilers were also seen to perform dust-bathing on wood shavings (Bokkers and Koene, 2003a), but under commercial conditions litter quality may limit this behaviour.

Bizeray et al. (2002c) projected bright moving spots of light onto the pen floor for one hour, four times per day, as an alternative means of increasing environmental complexity; they observed that birds exposed to this experimental treatment had worse leg health than birds housed under control conditions. The lights appear to have suppressed, rather than have stimulated, locomotion and foraging activity.

Scattering whole wheat onto the litter is not a successful strategy for increasing walking or foraging behaviour in broilers when a standard commercial diet is also provided *ad libitum* (Bizeray et al., 2002b; Jordan et al., 2011). In fact, Bizeray et al. (2002c) observed that GS under the wheat treatment was higher than for birds housed under control conditions. When the feed trough was removed and the food pellets were scattered in the litter an increase in walking and foraging was observed (Jordan et al., 2011).

The provision of toys (balls, plastic bottles, and mirrors) during the first three weeks of placement has been shown to decrease fearfulness during exposure to acute stressors (such as heat stress, noise and crating) when compared to a control group without enrichment (Altan et al., 2013). Novel objects generally only stimulate short-term increases in activity and interest, the reason Altan et al. (2013) regularly rotated the objects between pens in their study. The provision of varying environmental stimuli early-on appeared to make these broilers more adaptable to novelty and better able to cope with fear-inducing stimuli. Fear reduction should be an important goal of broiler enrichment as excessive fear reactions can have harmful effects such as panic (responsible for inducing mortality via 'smothers'), in addition to the negative physiological effects associated with chronic stress.

B5.6 Health benefits of enrichment

The provision of elevated structures may increase activity, reduce disturbances, and improve leg and foot pad health in broilers; careful design of the enrichment is required to ensure use (e.g. slow-grow broilers would be more likely to use platforms and bales than perches).

Providing greater environmental complexity via the provision of elevated structures has been shown to encourage increased physical activity (Bizeray et al., 2002b; Ventura et al., 2012; Bailie et al., 2013; Ohara et al., 2015; Bailie and O'Connell 2015). Bailie et al. (2013) observed leg health to be better in broilers housed under natural light and with the provision of straw bales, compared to birds without. Perch provision has been linked with improvements in several bone parameters. Birgul et al. (2012) reported greater angular bone deformation in broilers housed without perches, and lower TD in groups of broilers demonstrating high perch usage. Birds housed under greater environmental complexity (barrier perches) were observed to have greater symmetry in tibial length (Ventura et al., 2010) and an increased diameter of the tibia diaphysis, although TD itself was not reduced (Bizeray et al., 2002c). Several studies report no differences in walking ability (LeVan et al., 2000; Su et al., 2000; Hongchao et al., 2013); however, these studies also describe low perch use. Martrenchar et al. (2000) found that tibial breaking strengths were unrelated to perch provision or perch use, but even this study only reported a maximum of 5% of birds perching. Simsek et al. (2009a) also report bone quality to be similar between a group of fast-grow broilers provided with perches and a control group; however, they did not monitor perch use.

Further benefits of promoting perching and roosting include reduced contact between the skin and the litter and better distribution of birds vertically within the available space, allowing better circulation of air and improving ventilation of the litter surface. Results regarding the influence on elevated structures and contact dermatitis are variable and are likely to reflect different uptake in perch use between studies. Perch provision has been associated with less FPD (Ventura et al., 2010; Hongchao et al., 2013; Kiyma et al., 2016) while straw bale provision has been associated with a reduction in FPD in female broilers only (Ohara et al., 2015); other studies report no effect of perch provision on FPD (Su et al., 2000; Rodriguez-Aurrekoetxea et al., 2014) or HB (Su et al., 2000; Ventura et al., 2010; Hongchao et al., 2013). The lack of an association between perch availability and HB is understandable when you consider that birds with HB tend to be older, heavier, and lame and, therefore, unlikely to easily access a perch. The H:L ratio of birds housed with enrichment (perches and hay bales) was lower than in those without (Ohara et al., 2015), suggesting that an absence of enrichment was in some way more stressful. The provision of barrier perches and vertical panels to stimulate a more homogeneous distribution of broilers throughout the floor space (see B5.3 and B5.4) will benefit health and comfort by producing a more

even litter quality, better allow birds to escape disturbance and rest undisturbed, and reduce skin lesions otherwise caused by jostling for a space near the periphery walls.

B6. FACILITIES AND EQUIPMENT: OUTDOOR RANGE

B6.1 Factors influencing range use

Use of the range can be improved with the addition of artificial or natural cover (mature trees and bushes will encourage birds to actively explore areas further from the house); stocking the range with nutritional vegetation may encourage broilers outside to voluntarily access renewable food sources.

Unlike hens, most free-range broilers are allowed direct access to the range via open-sided houses or sheds, rather than raised pop-holes which they might find difficult to move through. Access to outside space does not however, guarantee that all of the birds will use it. In fact, in the majority of free-range commercial broiler systems many birds will never leave the houses, making them 'free-range' only in name. Range use (% of birds) varies widely between studies: 15% (Dawkins et al., 2003); 2-29% (Sosnówka-Czajka et al., 2007); 40-69% (Almeida et al., 2012); 37% (Rodriguez-Aurrekoetxea et al., 2014); 15% (Fanatico et al., 2016).

A number of factors have been reported to affect the ranging behaviour of broilers including bird characteristics, environmental variables and management regimes. Although breed differences in range use exist even among slow-growing broilers (Nielsen, 2004), these breeds generally spend more time outdoors, are more active, and use more of the range than either medium-growing (Almeida et al., 2012), or faster-growing strains (Nielsen et al., 2003b). Nielsen et al. (2003b) observed a faster-growing breed to have more dermal lesions and impaired mobility than a slow-grow breed, which explained their low use of the outdoor area; poor litter quality was also associated with the fast-growing breed, presumably due to them spending more time indoors, yet didn't encourage them outside. Foraging activity and time spent on the range has been seen to increase with broiler age (Almeida et al., 2012). Presumably the birds acquire greater confidence and familiarity of the range over time which then enables them to stay out for longer and explore a greater area. Seasonal and climatic conditions are of prime importance for range use, with more broilers observed outside in summer and on warm overcast days (Dawkins et al., 2003). Broilers demonstrate a diurnal rhythm of range use, with most birds observed outside around sunrise and before sunset, and least birds out at mid-day (Dawkins et al., 2003; Nielsen et al., 2003b; Fanatico et al., 2016). Almeida et al. (2012) report that a medium-grow breed would increase outdoor foraging activity in the evenings, but during the day the birds would remain inside or remain very close to the house exterior.

Range use appears to be associated with flock size; the more birds per flock, the lower the proportion of birds outside (Sosnówka-Czajka et al., 2007). Dietary regime can also influence range use. The high proportion of birds using the range in the study of Almeida et al. (2012), (medium-grow: 39.9%; slow-grow: 68.6%), may be explained by their restricted diet and that the range had been planted with nutritious forage vegetation (grass and clover or chicory). In the study of Nielsen et al. (2003b) birds provided with a moderate energy feed allowance were more likely to go outside than birds provided with low energy feed; however, the outside area in this case was just standard pasture so may have offered the birds no nutritional benefit. The observation that only a proportion of the flock use the range suggests that the outdoor environment (usually short grassland) is not favoured over the inside accommodation. Broilers provided with outdoor access often do not use the full range and are most often observed in the immediate vicinity of the house (Dawkins et al., 2003; Nielson, 2004; Fanatico et al., 2016). Broilers have been shown to prefer habitat containing trees and bushes than large expanses of short grass, especially when the habitat was located some distance from the house (Dawkins et al., 2003). Natural cover provides shelter from the elements and predators and increases range use, but established vegetation may not be present in all free-range operations and, if planted, will take time to mature and add environmental value. Jones et al. (2007) observed that the presence of young trees on the range (first 2 years of growth) did not have a significant impact upon welfare measures (including mortality and morbidity, leg health and ranging behaviour), or production parameters, compared to pasture access; however, by year 3, tree presence was associated with increased range use on sunny days. Although the incorporation of artificial structural enrichment into outdoor ranges (including plastic perches, screened shelters and overhead shade panels), did not increase the tendency of slow-grow broilers to go outside, it did encourage them to utilise more of the range, especially the area furthest from the sheds (Fanatico et al., 2016).

B6.2 Health and welfare benefits of range use

Provision of an outdoor space will enable broilers to perform a broader range of behaviours.

Providing broilers (of a suitable genotype) with outdoor access during part of their lives has many fundamental welfare benefits. It stimulates them to forage within, and explore, a changeable complex environment, encouraging activity and providing them with the space and stimulus to perform a broader range of behaviours. Broilers reared in free-range systems tend to demonstrate greater motor activity compared to those reared without free-range access (Nielsen et al., 2003b; Sosnówka-Czajka et al., 2007). Higher proportions of active behaviours such as walking, standing, spot-pecking, and preening are performed outdoors, while a higher percentage of feeding and resting behaviours are performed indoors by both fast- and slow-growing breeds (Skomorucha et al., 2007; Zhao et al., 2014; Fanatico et al., 2016; Ipek and Sozcu,

2017). Sosnówka-Czajka et al. (2007) observed that more constructive behaviour, including litter pecking and ground-scratching, was performed by birds housed within free-range systems, while more aggression was associated with broilers without outside access. Zhao et al. (2014) report a lower fluctuating asymmetry of tibia length in broilers with outdoor access, compared to broilers housed indoors, but also greater fearfulness and mortality levels.

Flocks with outdoor access generally have higher FPD scores than those housed indoors (Pagazaurtundua and Warriss, 2006; Sarica et al., 2014). However, low levels of hock burn have been reported (Sans et al., 2014). The conditions underfoot, particularly wetness, and hard, stony ground (Sans et al., 2014) are likely to be important risk factors. Broilers allowed access to range areas with trees and grass had better foot condition than broilers with grass alone, possibly due to better and more even range use (Dal Bosco et al., 2014). Managing the range to avoid wet areas and allow drying of the feet will likely be beneficial. Outdoor flocks have been shown to have better leg health (Sans et al., 2014; Ipek and Sozcu, 2017). Production parameters are generally lower in free-range compared to indoor systems due to increased activity levels (Zhao et al., 2014; Ipek and Sozcu, 2017).

B7. FEAR AND DISTRESS

B7.1 Fearfulness and sociality

Restraint elevates fearfulness and increases social reinstatement.

Fearfulness (as measured by tonic immobility) does not appear to be related to spontaneous activity or behavioural time-budgets (Bizeray et al., 2002d), but it has been positively linked to the expression of sociality. Restraint elevates fearfulness and was seen to increase social reinstatement in a runway test (compared to non-restrained controls) (Marin et al., 2001). As social affiliation was increased when the stimulus bird was familiar, this also demonstrates that broilers can distinguish between familiar and unfamiliar individuals in novel environments (Marin et al., 2001).

B7.2 Effects of parents, incubation

Incubating eggs under light improves post-hatch chick welfare, as reflected by reduced levels of stress and fearfulness.

Onbaşıl et al. (2008) observed that broilers (40 days old) produced by young breeders (32 weeks old) were more fearful than broilers produced by older breeders (48 and 61 weeks); H:L ratio was not affected by parent breeder age. Provision of light during incubation has been shown to be beneficial for reducing many measures of stress in chicks post-hatch, although optimal conditions for incubation are still unclear. Providing light during incubation (12L:12D or 24L:0D) has been shown to reduce the stress response following crating, including a reduction in corticosterone concentration, an increased antibody response, and produce lower composite physical asymmetry scores (considered to be an indicator of developmental stress), compared to 0L:24D (Archer et al., 2009; Archer and Mench, 2013; 2014; 2017). Özkan et al. (2012) also observed that incubating eggs under a 16L:8D photoperiod reduced plasma corticosterone, following regular handling of chicks at the hatchery post-hatch, compared to those that had been incubated in the dark. Birds not exposed to light throughout incubation were more fearful (as assessed via a dark-box emergence test, a tonic immobility test, an inversion test and an isolation test) at three weeks old than birds incubated under 12L:12D. Incubation under 1L:23D or 6L:18D had lesser, and less consistent, effects, in the same direction (Archer and Mench, 2014; 2017). These results demonstrate that the provision of light stimulation during embryogenesis produces chicks that are better adapted to the hatchery environment (indicated by long-term reductions in fearfulness and stress) and, as such, have improved post-hatch welfare.

B7.3 Fearfulness and hatchery procedures

Well-maintained chick handling machinery causes low-level physical stress to chicks.

Knowles et al. (2004) measured the physical accelerations and velocities experienced by broiler chicks as they pass through the handling systems at different hatcheries and compared this to the response of the chicks; measures of mortality, righting time (as a measure of disorientation) and tonic immobility were seen to reflect the range in physical 'handling' severity but chick welfare was overall deemed to be acceptable. The authors stress the importance of proper maintenance for chick handling machinery to avoid damage to chicks occurring from any further increase in physical stress (Knowles et al., 2004).

B7.4 Fearfulness and human contact

The number and quality of visits made by stockpeople to broiler sheds appears to be very important for many aspects of welfare; regular visual contact with the stockperson may reduce fear and stress in broilers following handling and crating.

Marin et al. (2001) observed that even brief physical restraint can elevate underlying fear levels in broilers and this effect can persist for at least one hour. Regular human (visual) contact between 1-21 days of age was sufficient to reduce fear and stress reactions (lower H:L ratio) to handling and crating, and improve antibody response in broilers, compared to

broilers that had never had human visual contact (Zulkifli et al., 2002). 'Pleasant' visual contact has been shown to be as effective as physical contact (pleasant or unpleasant) in reducing broiler stress following handling and crating. Broilers exposed to either daily 'pleasant' physical contact or daily 'pleasant' visual contact had lower fear and stress responses than a (non-handled) control group (Zulkifli and Azah, 2004); broilers exposed to unpleasant daily physical contact (inverted swinging by the legs) had lower H:L ratios than the controls, but demonstrated similar levels of fear. Subjecting broilers to 'pleasant' human contact (gentle stroking) has also been reported to reduce stress and fear reactions to transportation compared to a control treatment (no physical or visual contact), whilst broilers subjected to unpleasant handling (inverted swinging and aversive noise) had similar stress and fear responses to the control group (Al-Aqil et al., 2013).

Correlations between stockperson attitudes, broiler fear of humans and mortality have also been identified. The likelihood of birds withdrawing from an experimenter during a 'stroll test' was negatively associated with 'farmer job enjoyment', and positively associated with the speed that stockpeople moved through the shed and the belief that: 1) minimal time and training is required to manage broilers and, 2) husbandry is not important in determining productivity (Cransberg et al., 2000). Cransberg et al. (2000) also observed that first week mortality was positively correlated to the speed at which stockpeople moved through the shed, the time stockpeople remained stationary within the shed, and avoidance of the experimenter in the stroll test; high speed of movement (within the range 0.21 to 0.49 m/s) may thus provoke fear in the birds and prevent detection of welfare issues.

B8. SENSORY ENVIRONMENT

B8.1 Light and vision

Continuous or near-continuous lighting, and dim illumination (<10 lux) during the lights-on period, have negative effects on broiler behaviour and health; a photoperiod of 16L:8D appears to be appropriate for maximising broiler welfare. Behaviour patterns of broilers become synchronised when there is a pronounced intensity contrast between the light and dark period; this synchronised activity reduces sleep disturbance during dark periods.

Manipulation of photoperiod and light intensity is an important management tool used to regulate broiler production and welfare by modulating various physiological and behavioural pathways.

B8.1a Photoperiod

Continuous light (24L:0D) is normally provided during the first 4 days post-hatch, the brooding period, this encourages chick activity and is considered beneficial in stimulating them to start feeding. No research on the effects of providing continuous light for a slightly fewer or slightly greater number of days post-hatch was discovered. A number of different types of lighting schedule are used commercially during the grow-out phase, including continuous or near-continuous lighting, restricted continuous lighting (the provision of a single continuous light period, followed by a single continuous dark period, within a 24 hour period) and intermittent lighting (the provision of shorter periods of light and dark, cycled multiple times within a 24 hour period). Long photoperiods are considered necessary to ensure maximal feed intake and, therefore, fast growth (Malleau et al., 2007). Within the EU, lighting must follow a 24-hour rhythm and include periods of darkness lasting at least six hours in total, with at least one uninterrupted period of darkness of at least four hours, excluding dimming periods.

Continuous or near-continuous daylength has a negative impact on many aspects of broiler health. H:L ratios are generally higher under continuous or near continuous light (24L:0D or 23L:1D) than under constant light (16L:8D: Onbaşilar et al., 2008; Coban et al., 2014; Das and Lacin, 2014; Toplu et al., 2016). The effects of intermittent lighting programmes are less clear, as studies differ in lighting regime. Das and Lacin (2014) observed higher H:L ratios under continuous light than intermittent light (4L:2D), whereas other studies found no difference (1L:3D: Onbaşilar et al., 2007; 2L:2D after natural daylight: Petek et al., 2010). No difference in H:L ratio was also found when comparing continuous light with an increasing light regime (14L:10D increasing to 23L:1D over the grow-out period) (Dereli Fidan et al., 2017). Coban et al. (2014) observed that the H:L ratios of broilers reared under a self-photoperiod regime (i.e. provided with continuous light and a dark chamber) were lower than birds reared on continuous light without access to a dark chamber, but higher than birds raised under constant light (16L:8D). Plasma corticosterone concentration appears to be unaffected by lighting regime (Olanrewaju et al., 2010; 2013; 2014a), as does blood glucose (Onbaşilar et al., 2007; 2008).

Van der Pol et al. (2015) observed that exposing newly hatched chicks to continuous light (24L:0D) for 4 days increased leg bone development and leg bone asymmetry, compared to chicks exposed to intermittent lighting (2L:1D or 2L:6D). The authors hypothesise that a reduction in activity (although not measured in this study) associated with longer dark periods was responsible for slowing bone development. Van der Pol et al. (2015) also observed that light dimming was associated with lower bone asymmetry than abrupt light-dark transitions, which may also be indicative of lower environmental stress. Other studies did not detect a difference in relative asymmetry of leg bones in broilers reared under continuous light and either intermittent light (Onbaşilar et al., 2007) or constant light (Onbaşilar et al., 2008). Exposure to chronic stress is often

seen to suppress immunity. Intermittent lighting (1L:3D), but not constant lighting (16L:8D), was seen to improve immune function compared to continuous lighting (24L:0D); spleen weight remained unaffected by lighting regime (Onbaşilar et al., 2007; 2008).

An 8 h scotoperiod generally appears to be associated with low fear levels. Fearfulness has generally been found to be higher under continuous or near-continuous light than under constant light (16L:8D) (Sanotra et al., 2002; Onbaşilar et al., 2008; Bayram and Özkan, 2010; Toplu et al., 2016). Onbaşilar et al. (2007) observed tonic immobility to be lower in broilers housed under intermittent light (1L:3D) than continuous light; however no difference was observed under a different intermittent light regime (4L:2D; Das and Lacin, 2014).

A longer dark period was associated with broiler flocks appearing to be more content, positively occupied, and energetic (Bassler et al., 2013), in accordance with reports that a dark period increases physical activity during light (e.g. Schwan-Lardner et al., 2012). The same flocks were also scored as agitated, unsure, tense, nervous, scared and fearful (Bassler et al., 2013). This may reflect some limitations of the qualitative behavioural analysis methodology.

Leg health, leg bone quality and FPD benefit from a longer scotophase (see B3.3g and B3.4a). Lewis and Gous (2009) report a negative linear relationship between eye weight and photoperiod (2-21 h light). Heavier eyes (macrophthalmia) are also reported in continuously illuminated birds (Lewis and Gous, 2009; Schwan-Lardner et al., 2013). These results indicate that normal ocular development in broilers requires a maximum photoperiod of 20 h and that short photoperiods, in addition to continuous illumination, may be harmful for eye health. Restricted continuous and intermittent lighting programmes are used commercially to limit early growth rates and limit losses associated with metabolic disorders (sudden death syndrome and ascites) and leg problems (Scott, 2002). Some studies report lower mortality under shorter day-lengths (Brickett et al., 2007; Lewis et al., 2010; Schwan-Lardner et al., 2013), while others do not (Lien et al., 2007; Petek et al., 2010; Coban et al., 2014).

The majority of studies find no effect of photoperiod upon production parameters (Lien et al., 2007; Onbaşilar et al., 2008; Bayram and Özkan, 2010; Lewis et al., 2010). Das and Lacin (2014) observed higher production parameters under continuous light than constant (16L:8D) or intermittent lighting (4L:2D), while another study found the opposite; production parameters were improved in broilers raised under intermittent light (4L:4D) compared to continuous light (Yang et al., 2015).

Activity (including the percentage of time spent standing, walking, feeding, drinking, preening, stretching, dust-bathing and litter pecking) decreases with increasing day-length (Sanotra et al., 2002; Bayram and Özkan, 2010; Schwan-Lardner et al., 2012) regardless of age or stocking density. Schwan-Lardner et al. (2012) observed no behavioural advantage associated with the longest scotoperiod they tested (14L:10D), so they recommend a photoperiod of 16L:8D as optimum. Bayram and Özkan (2010) also observed that birds maintained under a 16L:8D photoperiod displayed greater sociality (as assessed by social reinstatement runway tests), compared to birds exposed to continuous lighting. Interestingly, dust-bathing was not observed in older broilers reared under 23L:1D (Schwan-Lardner et al., 2012). The reduction (or elimination) of locomotive, exploratory, social, comfort and nutritive behaviours, including those that are highly motivated, are likely to indicate reduced welfare in birds raised under constant, or near-constant, light.

Commercial broiler production is not generally designed to accommodate sleep and rest. The initial provision of continuous or near continuous bright light to chicks following placement within barns encourages high activity. Chicks attempting to sleep or rest are likely to encounter continual disturbance as large numbers of flock-mates move between the drinkers and feeders. Malleau et al. (2007) observed that chicks housed under long days (19L:5D) spent a lower proportion of the light period in active behaviour but had a greater total activity than chicks maintained on a simulated brooding cycle (40 min L: 40 min D throughout the 19 h light period). Chicks on the brooding cycle demonstrated high (synchronised) activity levels when the lights were on, and very low (synchronised) activity levels when the lights were off (Malleau et al., 2007). The authors hypothesise that (since production parameters were unaffected by longer dark periods) using lighting regimes to synchronise behaviour and increase opportunities for undisturbed rest may provide more welfare benefits to young chicks than the constant restricted lighting regimes currently in use (Malleau et al., 2007). Exposing broilers to 4+ hours of darkness also enables the development of flock behavioural, and circadian, rhythms during the photophase, which are not seen under near-constant light (Schwan-Lardner et al., 2014); shorter day lengths (14L:10D and 17L:7D) increase the expression of synchronised behavioural rhythms. These results support the hypothesis that birds reared under constant, or near-constant, light are at a higher risk of suffering from sleep fragmentation (i.e. are sleep-deprived). The provision of a distinct photoperiod could improve broiler welfare by promoting pronounced behavioural rhythms within a flock, and allowing them a distinct period of rest during the scotophase, as well as reducing disturbance from flock-mates during this period of rest (Alvino et al., 2009b).

B8.1b Light intensity

Chicks are exposed to bright light during the first week of life to stimulate feeding. Subsequently, broilers are typically housed under dim lighting for the remainder of the production cycle. Despite considerable research on light intensity, there is still a debate on the optimum level to be used for intensively housed broilers. Within the EU, lighting requirements state that a light intensity of at least 20 lux during the light phase must be provided at all ages. In other countries, including

Brazil, it is common to reduce the light intensity from 20 lux to 5 lux by 14-21 days and then maintain this for the remainder of the grow-out period (Araújo et al., 2015).

Light intensity (delivered via a constant restricted photoperiod, 16L:8D) influences diurnal patterns of activity and behaviour. Broilers maintained under a high daytime light intensity (50-200 lux) throughout rear demonstrated greater flock behavioural synchrony than birds housed under 1 lux (Alvino et al., 2009a; Blatchford et al., 2009). Birds under the higher light intensity were also more active and fed more during the photophase (and were less active and fed less during the scotophase) than birds maintained at 1 lux (Blatchford et al., 2012). Birds raised under dim lighting (5 lux) demonstrate pronounced dispersal of inactive and active behaviours over the entire photoperiod and lack behavioural synchronisation, presumably due to the low light-dark contrast between the scotophase and photophase having dampened their behavioural rhythms (Alvino et al., 2009a; Blatchford et al., 2009; 2012). In addition, broilers reared under conditions of high illumination (200 lux) were observed to perform fewer, longer, less interrupted resting bouts during the scotophase than birds reared under low (5 lux) or intermediate (50 lux) light intensity (Alvino et al., 2009b).

Dim lighting (<5 lux) has been associated with reduced activity compared to brighter lighting (20-320 lux) (Blatchford et al., 2009; Deep et al., 2012; Senaratna et al., 2016); however, Kristensen et al. (2006b; 2007) report that activity in 6 week old broilers was similar under dim and bright light intensities (5 or 100 lux, adjusted to fowl perceived illuminance). Although Kristensen et al. (2006b) observed that alternating the light intensity every 2-4 hours between 5 and 100 lux increased broiler activity, this could not be replicated in a subsequent study where the light was alternated between 10 and 200 lux four times per day (Sherlock et al., 2010). Deep et al. (2012) observed that broilers exposed to a very low light intensity (1 lux) foraged and preened less than birds housed under higher light intensities. A reduction in foraging behaviour may be linked to a decrease in visual acuity under dim lighting, while a decrease in preening (a key comfort behaviour) may possibly indicate reduced welfare.

Although only a few recent studies correlate physiological welfare measures with light intensity (no study has targeted light intensities above 25 lux) there is little evidence to suggest that exposure to any light intensity between 0.2 and 25 lux is stressful. Dereli Fidan et al. (2017) observed a higher H:L ratio in birds housed in 20 lux than in birds exposed to a lighting treatment that reduced from 5 to 1.25 lux over the duration of rear, while Lien et al. (2007) observed no difference in H:L ratio under conditions of 1 or 10 lux. Exposure to light intensities between 0.2-25 lux did not influence plasma corticosterone concentration either (Olanrewaju et al., 2008; 2010; 2013; 2014a; 2014b). Bayraktar et al. (2012) observed that the use of two halogen lamps to provide spot lighting (10 + 10 lux or 10 + 5 lux) in poultry houses maintained under dim lighting (filament: 10 lux) improved some welfare markers (reduced glucose concentration and increased bursa of fabricius size) compared to a control, while tonic immobility and mortality remained unaffected.

Very low light intensities (0.5-5 lux) have been associated with higher GS (Blatchford et al., 2012), increased FPD (Deep et al., 2010; 2013; Senaratna et al., 2016), HB, and breast blisters (Senaratna et al., 2016) compared to birds reared under brighter light (10-320 lux), which are likely to be associated with higher body mass (Lien et al., 2007; Blatchford et al., 2012; Senaratna et al., 2016). However, other studies have not observed an increase in GS (Blatchford et al., 2009; Deep et al., 2013) or contact dermatitis (Blatchford et al., 2009) under dim lighting (0.5-5 lux) compared with brighter lighting (10-200 lux). As with continuous or near-continuous lighting, many studies have shown that broilers reared under low lighting (0.5-1 lux) had larger heavier eyes (associated with choroid inflammation and apparent retinal degeneration) than birds reared under brighter light (10-200 lux), which could indicate impaired vision (Deep et al., 2010; 2013; Blatchford et al., 2009; 2012). Mortality appears to be unaffected by light intensity (Kristensen et al., 2006b; Lien et al., 2007; Blatchford et al., 2009; Deep et al., 2013; Olanrewaju et al., 2014b).

B8.1c Lighting source

Compact fluorescent lighting (CFL) and LED lighting have both been deemed suitable alternatives for incandescent light bulbs in broiler facilities, since they cause no detriment to broiler growth performance or welfare indices, including ocular development, walking ability, and mortality (Olanrewaju et al., 2015a; 2015b; 2016). Six week old broiler chickens were seen to prefer biolux and warm-white fluorescent lighting (closest to daylight in spectral composition) over incandescent and spectral sensitivity matched light, irrespective of the light intensity; more preening was observed under biolux light (Kristensen et al., 2007). Cold cathode fluorescent lamps are a less appropriate choice, as their use has been associated with lower body weights and higher H:L ratios than recorded under incandescent lighting (Rogers et al., 2015). Huth and Archer (2015a) report that light provided by LED bulbs (particularly a 'Once Innovations' bulb) was linked with improved welfare and productivity, including lower physical asymmetry, H:L ratio, plasma corticosterone and plumage, HB and FPD scores, smaller eye dimensions, increased feed conversion and had better plumage than recorded from broilers housed under dimmable CFL. Since production performance parameters have also, independently, been reported to be greater in broilers exposed to LED lighting than birds housed under CFL (Mendes et al., 2013) and as no behavioural differences have been observed between the two (Araújo et al., 2015), new generation, energy efficient, LED bulbs look to be the future choice for lighting broiler sheds.

Fear responses may be affected by exposure to different lighting colours and sources. Sultana et al. (2013) report that birds reared under Red and Red-Yellow LED light were more fearful (tonic immobility) than birds reared under Blue LED. Huth and Archer (2015a) found that broilers reared under light from LED bulbs were less fearful than broilers reared under

compact fluorescent lighting; however, Olanrewaju et al. (2016) found no differences in tonic immobility when comparing different light treatments (compact fluorescent lighting, a neutral-LED bulb and a cool poultry-specific filtered LED bulb). More research into behavioural effects of LED colour temperatures (the range from 'warm' red or orange colours through to 'cool' white and blue tones) would prove very useful as there are many different options available. Although broilers were not seen to demonstrate a preference between yellow and white LED lighting (Mendes et al., 2013), a different study reported that birds demonstrated a preference for (spent more time under) a cold-white than a neutral-white LED light (Riber, 2015). Birds reared in groups under Red and Red-Yellow LED light demonstrated more walking behaviour than birds reared under Blue LED, which spent more time inactive (Sultana et al., 2013). The use of light colour to stimulate activity from an early age could have many health and welfare benefits.

B8.1d Light during incubation

Huth and Archer (2015b) report that the provision of LED lighting (12L:12D; 250 lux) during embryogenesis in commercial broiler eggs improves chick quality (fewer defects), and lowers physical asymmetry and H:L ratios (i.e. reduces post-hatch chick stress susceptibility), compared to dark incubation.

B8.2 Sound, noise and hearing

Exposure to noise above 70 dB induces a rapid physiological stress response in broilers, although they may be able to adapt, at least partially, to continuous exposure.

Although some physiological evidence has been collated for loud noise being, at least, transiently stressful to broilers, as well as potentially having negative implications for production, no recent studies have assessed what noise levels broilers find aversive or consider how noise levels impact upon behaviour. An increase in H:L ratio has been observed following regular exposure of broilers to loud noise (95 dB: 120 min/day, Lazarevic et al., 2000), and following exposure to intermittent noise (at a level of 80 dB, not 70 dB: Bedáňová et al., 2010a). Following 10-14 min exposure to loud noise (100 dB) plasma corticosterone and glucose levels were seen to increase in end-of-rear broilers, above that of a control group (background noise: 50 dB), before decreasing back to baseline at 28 min, following continuous exposure (Bedáňová et al., 2010b). This indicates that continuous exposure to sound at 100 dB initially triggered a stress response, but a level of adaptation may have been possible. Chloupek et al. (2009) also observed corticosterone levels to be raised after acute (10 min) noise exposure at both 80 dB and 100 dB; however, in this instance, no effect was seen for glucose, nor was any difference in tonic immobility detected. Regular experience of loud noise also appears to have a negative effect upon production parameters. Following only 7 days exposure to intermittent noise (70 or 80 dB) experimental broilers already displayed a significant decrease in live body weight compared with the control group (Voslarova et al., 2011).

B8.3 Olfaction

Not much is known about olfaction in broilers; however, they will actively avoid exposure to ammonia concentrations above 20 ppm.

While the effects of ammonia on broiler health and production parameters are reasonably well understood (see B9.2), the effects on behaviour are not. If given the opportunity, broilers will avoid ammonia concentrations commonly found on poultry units. Following a series of choice tests broilers were seen to prefer fresh air (0 ppm) to an ammoniated atmosphere (10-40 ppm) (Wathes et al., 2002), and were observed to spend the majority of their time in low NH₃ concentrations (4 and 11 ppm) rather than higher concentrations (20 and 37 ppm), even if they had previously been housed (acclimatised) under 19 ppm (Jones et al., 2005b).

B8.4 Thermal comfort

The risk of hyperthermia increases with age and stocking density, as heat production increases and floor space decreases. Heat stress can be mitigated via the use of adequate ventilation, lowering stocking density, the provision of cooled perches, dietary supplementation with ascorbic acid and by utilising heat-tolerant breeds.

B8.4a Thermoregulation

The risk of thermal discomfort due to high temperatures (hyperthermia) increases towards the end of the grow-out period as birds get bigger, become better insulated, eat more food, and generate more heat. In addition, inter-bird spacing declines, diminishing the opportunity for heat dissipation (an effect that is exacerbated at high stocking densities, especially in warmer climates). High stocking densities favour radiant transfer from bird to bird and heat held within the floor litter becomes less easily dissipated. Reiter and Bessei (2000a) demonstrated that the temperature beneath the litter surface, at the litter surface, and 10 cm above the litter surface (at bird level) increased significantly with increasing stocking density, and that the temperature at bird level was reduced immediately when the birds were removed.

Thermal discomfort including hypothermia and hyperthermia can be detected via behavioural assessment. When the environmental temperature is too low broiler chicks huddle to conserve heat, especially when they have not yet become effective at homeothermy. As the birds grow and the environmental temperature rises (with increasing stocking density) to

equal body temperature passive heat loss is impaired (Reiter and Bessei, 2000a). Broilers reduce hyperthermia by: decreasing heat production (reduce activity levels), increasing active heat dissipation (increase respiration), and by performing behavioural thermoregulation (hold their wings out away from the body and avoid contact with flock-mates) (Arnould and Faure 2004; Lolli et al., 2010). Panting is commonly observed in broiler flocks stocked at densities ≥ 20 kg/m² (Lolli et al., 2010) and increases with age (Arnould and Faure 2004; Baeza et al., 2012) and stocking density (McLean et al., 2002; Zhao et al., 2013). At high stocking densities female broilers were seen to increase panting from two weeks old (McLean et al., 2002), indicating that females may be susceptible to thermal discomfort at an earlier age than males (despite having a lower feed intake and body mass). The Welfare Quality® assessment protocol for broilers incorporates measures of the proportion of birds showing huddling or panting as indicators of thermal discomfort (Welfare Quality®, 2009).

B8.4b Heat Stress: welfare impact

Sandercock et al. (2006) demonstrate that genetic selection for increased growth in broiler lines has compromised their thermoregulatory capacity leading to detrimental consequences for muscle function; plasma creatinine kinase activity (indicative of heat stress-induced myopathy) was higher in broilers than laying hens. Azad et al. (2010) also observed muscle damage in fast-growing broiler breeds following chronic heat stress; this damage was greater in broilers than a laying strain and was associated with depressed growth rates.

Exposure to high ambient temperatures during rearing and crating is highly stressful for broilers; high temperatures exaggerate fear responses and further compromise health and welfare by lowering immunity. Hyperthermia has been shown to increase the H:L ratio (Altan et al., 2003; Akşit et al., 2006; Skomorucha et al., 2010; Toplu et al., 2014), plasma glucose (Akşit et al., 2006; Toplu et al., 2014), fearfulness (Altan et al., 2003; Toplu et al., 2014), blood corticosterone (Al-Aqil et al., 2009; Quinteiro-Filho et al., 2010; Skomorucha et al., 2010; Toplu et al., 2014; Najafi et al., 2015), heat shock protein (hsp) 70 expression (Toplu et al., 2014; Najafi et al., 2015), ovotransferrin, α 1-acid glycoprotein (Najafi et al., 2015), and to decrease immune reactivity (Toplu et al., 2014), macrophage activity and spleen weights, and induce intestinal inflammation (Quinteiro-Filho et al., 2010) in broilers. Ross 308 broilers appear to be less tolerant of elevated air temperature than Hybro or Hubbard Flex breeds, as evidenced by increased mortality, fear responses (as measured by tonic immobility) and physiological stress measures (blood corticosterone and H:L ratio), which makes them less suited for rearing under hot climates (Skomorucha et al., 2010). In addition, heat stress also reduces meat quality and lowers production parameters (Akşit et al., 2006; Al-Aqil et al., 2009; Azad et al., 2010; Quinteiro-Filho et al., 2010; Najafi et al., 2015). Towards the end of rear Jones et al. (2005a) also observed faecal corticosteroid levels to be greater with increasing RH.

B8.4b Heat Stress: mitigation

In addition to whole-house management (see B9.1b for stocking density effects, and B9.4) other measures can be taken to mitigate heat stress. Akşit et al. (2010) observed that chicks subjected to heat acclimatisation within the egg (39.5 °C, 6 h/day, 10-18 d) and during brooding (35 °C) had lower H:L ratios than 'control' chicks (incubated at 37.5 °C) following heat stress. Heat conditioned broilers (36 °C, 24 h, 5 d) had lower H:L ratios, tonic immobility duration, serum corticosterone, glucose, hsp 70 expression, and greater immune reactivity (35 °C, 6 h/day, 22-42 d) compared with non-treated controls (Toplu et al., 2014).

Dietary modifications (particularly the use of supplements) appear to have some success in counteracting the negative physiological effects of heat stress in broilers. Toplu et al. (2014) observed that broilers fed a diet supplemented with ascorbic acid (AA) (500 mg/kg L-ascorbic acid) had lower H:L ratios, fearfulness, serum corticosterone, glucose, hsp 70 expression, and greater immune reactivity, following heat stress (35 °C, 6 h/day, 22-42 d) compared with non-treated controls. Similarly, the exposure of young broilers fed an AA-supplemented diet (500 mg/kg L-ascorbic acid) to high cyclic temperatures (21-30-21 °C) was seen to reduce plasma corticosterone and hsp 70 expression compared to birds fed a control diet (Mahmoud et al., 2004). Under conditions of heat stress dietary supplementation with vitamin E was seen to improve broiler immunity (Niu et al., 2009), while dietary glutamine decreased plasma corticosterone (Dai et al., 2011), compared to a control diet. In broilers exposed to heat stress (21-42 d), a period of feed withdrawal (8 h daily) was observed to improve welfare measures (decrease H:L ratio and tonic immobility) compared to a group fed *ad libitum* (Uzum and Toplu, 2013), presumably by reducing broiler-generated heat from feeding activity and metabolism. Sohail et al. (2012) found that broilers fed with a commercial diet containing *Bacillus* spp. (Protexin, Probiotics International LTD, UK) had a lower corticosterone response to a heat stressor (constant at 35 °C for 42 days) and also showed better feed conversion and better intestinal microarchitecture.

Cooled perches or zonal cooling has been recommended as an economical means of potentially relieving heat stress and minimising production losses under hot climatic conditions; success has been achieved via the provision of cooled perches. Increased perching is seen under high ambient temperature and towards the end of the grow-out period (Estevez et al., 2002; Okelo et al., 2003). Cool roost broilers have been shown to have lower mortality (Okelo et al., 2003), pant less, have lower plasma glucose, less contact dermatitis, increased plumage condition (Zhao et al., 2012; 2013), and

higher production parameters (Estevez et al., 2002; Okelo et al., 2003; Zhao et al., 2012; 2013) than birds provided with uncooled perches or without perches.

Feather coverage, in particular, hinders the dissipation of excessive internal heat in broilers commercially reared under hot climates. Genotypes with reduced plumage coverage, such as naked-neck breeds are, therefore, commonly favoured; the naked-neck genotype seems to be more heat resistant than a standard feathered breed (Rajkumar et al., 2011); H:L ratios were lower and production parameters were better than the standard breed under high ambient temperatures.

B9. HANDLING AND MANAGEMENT

B9.1 Stocking density and group size

Although high stocking density has a negative influence on many aspects of broiler welfare, an imposed limit on stocking density that does not consider other aspects of the broilers' environment is unlikely to substantially benefit animal welfare; failings in environment, nutrition and genetics will also require addressing.

B9.1a Stocking density and behaviour

Unlike layers, there is little evidence that group size alters the behaviour of broilers (Reiter and Bessei, 2000b; Weeks et al., 2000). Although a decrease in locomotor activity with increased density has often been reported (Hall, 2001; Lolli et al., 2010; Simitzis et al., 2012; Ventura et al., 2012), this association is often not observed (Cornetto and Estevez, 2001a; McLean et al., 2002; Buijs et al., 2011a). Reiter and Bessei (2000b) report that walking and ground scratching were negatively associated with stocking density towards the end of the grow-out period, but this observation was better explained by litter conditions, ambient temperature (increased due to microbial activity within the litter and the inhibition of air circulation) and social stimulation, rather than physical space restrictions. Litter directed behaviour was negatively correlated to stocking density in some studies (Hall, 2001; Sanotra et al., 2002; Buijs et al., 2011a; Ventura et al., 2012), but not in others (Cornetto and Estevez, 2001a; McLean et al., 2002). Bokkers et al. (2011) modelled the physical space needed for broilers to perform non-social behaviours at different stocking densities; they calculated that broilers reared at high stocking densities (>16 broilers/m²) will experience physical compression, with obvious behavioural ramifications.

The temperature of the litter surface increases with increasing stocking density (Reiter and Bessei, 2000a; Lolli et al., 2010). Lolli et al. (2010) identified more behavioural changes associated with stocking density in a feathered broiler strain than a non-feathered strain, leading them to conclude that behavioural alterations observed under high density were likely to have a temperature component (in addition to physical space restrictions). Perch availability (and thus use) has been considered a means of minimising some of the negative consequences of stocking density (e.g. insufficient air circulation at floor level); however, the relationship between stocking density and perch use are, as yet, unclear. Some studies have observed perch use to increase with higher stocking densities (Martrenchar et al., 2000; Pettit-Riley and Estevez, 2001), whereas other studies report the opposite (Ventura, 2010; 2012). Hongchao et al. (2013) observed that birds maintained at an intermediate stocking density (16 broilers/m²) perched more frequently on wooden or PVC perches than birds housed at either a lower (12 broilers/m²) or higher density (20 broilers/m²). Since Ventura et al. (2012) did not provide sufficient perch space to allow all birds access there is a possibility that the available perch space became saturated. Perch allowance appears to be important since a 50% reduction in total perch length (same flock size) has been seen to dramatically reduce the proportion of birds roosting (24% versus 7%) (Nielsen, 2004). Absolute group size does not appear to be important for influencing perching behaviour (Martrenchar et al., 2000); however, no mention of perch space allocation per bird was made in this study.

Increasing stocking density fragments behaviour and prevents prolonged activity, e.g. walking bouts decrease in length and locomotion slows (Hall, 2001; Leone and Estevez, 2008; Buijs et al., 2011a), presumably, due to a barrier effect, whereby the birds become obstacles (e.g. Collins, 2008). Recent studies have showed a consistent effect of stocking density on disturbance; at high stocking densities broilers frequently have their sleep and rest interrupted by other birds (Hall, 2001; Cornetto et al., 2002; Dawkins et al., 2004; Ventura et al., 2012). Reiter and Bessei (2000b) observed small groups ($n=20$) of broilers to demonstrate a short (20 minute) cycle of activity and resting, but this rhythm disappeared in larger groups, and at higher stocking densities, due to a lack of behavioural synchronisation within the flock. These disturbances are a likely cause of the fragmentation of behaviour, including resting bouts, with increased density (Hall, 2001; Buijs et al., 2011a). In addition to specific behavioural alterations, density effects on space usage have also been reported. At low density (2 birds/m²) broilers were observed to remain near the drinkers and feeders, while at high density (15 birds/m²) broilers sought out floor space with less disturbance away from the feeders and drinkers (Arnould and Faure, 2004). Buijs et al. (2011a) observed that broilers stocked at a density of ≥ 15 kg/m² increased their distance from one-another, as would be expected if they considered close proximity to pen-mates as being aversive. In addition, Buijs et al. (2011b) observed that broilers were strongly motivated to work (crossing a barrier) for increased floor space allowance.

Fearfulness (tonic immobility) can be raised at high stocking densities (18-22 broilers/m²: Onbaşlar et al., 2008; Buijs et al., 2009; Uzun and Toplu, 2013); although, this is not always observed (Skomorucha et al., 2009; Ventura et al. 2010;

Das and Lacin, 2014). Skomorucha and Muchacka (2007) observed an increase in tonic immobility with increasing density (13-17 broilers/m²) only when birds were housed in a cage system and not when housed on litter.

B9.1b Stocking density, physiological stress and bird health

As broilers have been intensively selected to have a very high food motivation (e.g. Bokkers and Koene, 2004) any reduction in feeding behaviour (whether of a voluntary or competitive cause) may be considered 'abnormal' and, thus, potentially indicate impaired welfare. Many studies report that feed intake decreases with increasing density (Thomas et al., 2004; Dozier et al., 2006; Villagr  et al., 2009; Beloor et al., 2010; Simsek et al., 2011; Simitzis et al., 2012; Abudabos et al., 2013a; Hongchao et al., 2013; Sun et al., 2013; Uzum and Toplu, 2013; Zhao et al., 2013; Das and Lacin, 2014; Jiao et al., 2014; Shakeri et al., 2014; Cengiz et al., 2015; Khosravinia, 2015; Tsiouris et al., 2015; Qaid et al., 2016), although others have not (Imaeda, 2000; McLean et al., 2002; Ravindran et al., 2006; Sirri et al., 2007; T rkyilmaz, 2008). Similarly, there appears to be a clear link between increased stocking density and a reduction in growth rate (Thomas et al., 2004; Dozier et al., 2006; Sirri et al., 2007; Skomorucha et al., 2009; Villagr  et al., 2009; Beloor et al., 2010; Petek et al., 2010; 2014; Sekeroglu et al., 2011; Simsek et al., 2011; Simitzis et al., 2012; Sun et al., 2013; Uzum and Toplu, 2013; Das and Lacin, 2014; Cengiz et al., 2015; Qaid et al., 2016) although, again, several studies did not report an effect (e.g. Buijs et al., 2009; Ventura et al., 2010; Tsiouris et al., 2015).

Stocking density does not appear to be negatively correlated with mortality (Feddes et al., 2002; Dawkins et al., 2004; Thomas et al., 2004; Dozier et al., 2006; Ravindran et al., 2006; Sirri et al., 2007; Meluzzi et al., 2008b; T rkyilmaz, 2008; Buijs et al., 2009; Villagr  et al., 2009; Petek et al., 2010; Ventura et al., 2010; Sekeroglu et al., 2011; Simsek et al., 2011; Gomes et al., 2014; Shakeri et al., 2014; Najafi et al., 2015; Simsek and Ozhan, 2015), at least in the absence of extreme ambient temperature. Pettit-Riley and Estevez (2001) report the percentage mortality due to heat stress to increase with stocking density, whereas total mortality remained unchanged. In the first few weeks of rearing higher stocking densities may even decrease mortality (Heier et al., 2002), presumably due to increased temperatures at the litter level. Gomes et al. (2014) report that birds subjected to a higher stocking density (10 vs 16 broilers/m²) had morphological signs of enteritis and, following experimental infection with *Salmonella enteritidis*, demonstrated decreased macrophage activity and increased *Salmonella* invasion in the liver. Tsiouris et al. (2015) report that high stocking density (15 vs 30 broilers/m²) increased broiler chick susceptibility to an experimental model of necrotic enteritis and had a greater severity of necrotic lesions.

Experimental studies demonstrate that lameness increases above a stocking density of 33-42 kg/m² (S rensen et al., 2000; Hall, 2001; Thomas et al., 2004; Sun et al., 2013; Das and Lacin, 2014). Buijs et al. (2009) present evidence for deteriorations in leg health occurring at even lower densities; they observed pronounced differences in LTL measures in birds maintained at 6 and 23 kg/m². Studies conducted on commercial farms provide additional evidence for decreased walking ability at higher stocking densities (Dawkins et al., 2004; Knowles et al., 2008). Although some studies report no effect of stocking density on leg deformations (S rensen et al., 2000; Dawkins et al., 2004), there is evidence for increased tibia curvature and decreased tibia length and strength at higher densities (Buijs et al., 2012; Sun et al., 2013), and greater tibial asymmetry (Ventura et al., 2010), even though broilers grow more slowly at high density (Dawkins et al., 2004; Sun et al., 2013). There does not appear to be any evidence linking stocking density with valgus-varus deformities (S rensen et al., 2000; Arnould and Faure, 2004), TD (S rensen et al., 2000; Buijs et al., 2012; Das and Lacin, 2014), or bone strength (Tablante et al., 2003; Sirri et al., 2007).

A positive relationship between FPD severity and stocking density has often been reported (S rensen et al., 2000; Hall, 2001; Arnould and Faure, 2004; Thomas et al., 2004; Dozier et al., 2006; Haslam et al., 2007; Meluzzi et al., 2008a; Onba ilar et al., 2008; Buijs et al., 2009; Simsek et al., 2009b; Villagr  et al., 2009; Petek et al., 2010; 2014; Ventura et al., 2010; Zhang et al., 2011; Kyvsgaard et al., 2013; Sun et al., 2013; Zhao et al., 2013; Shakeri et al., 2014; Khosravinia et al., 2015), associated with increased litter moisture and pH (McLean et al., 2002; Thomas et al., 2004; Dozier et al., 2006; Simsek et al., 2009b; Petek et al., 2010; 2014; Khosravinia et al., 2015). However, stocking density is not a reliable indicator of bird welfare since several studies report no direct impact on FPD development (Martrenchar et al., 2002; Dawkins et al., 2004; Haslam et al., 2006; Sirri et al., 2007; Meluzzi et al., 2008b; Allain et al., 2009); with good litter management and effective environmental control it is still possible to maintain litter quality under high stocking densities. Skin scratches are also more prevalent at higher stocking densities (Hall, 2001; Dawkins et al., 2004; Allain et al., 2009; Arruda et al., 2016), probably due to increased disturbances when birds jostle for space at the drinkers and feeders or at a preferred lying up spot.

On the basis of observations of (shallow and deep) panting observed in broilers maintained at different stocking densities (28-40 kg/m²) McLean et al. (2002) conclude that densities of less than 34 kg/m² provide better thermal comfort (and hence welfare). Uzum and Toplu (2013) examined the interaction of heat stress (32-35  C for 8 h per day for 21 days) and stocking density on welfare. Broilers coped better (lower H:L ratio and tonic immobility durations) with heat stress at a stocking rate of 12 birds/m² than at 18 birds/m². This was supported by Abudabos et al. (2013b) which showed that broilers at a low stocking rate of 26.5kg/m² (12 birds/m²) were better able to dissipate a heat overload than birds at a stocking rate of 45 kg/m² (20 birds/m²).

Many inconsistencies exist within the literature regarding the correlation of physiological measures of stress with stocking density, results tend to vary according to the parameter measured, as well as between studies utilising the same measures and similar stocking densities. Many studies report an increase in H:L ratio towards the end of the growing out period at around 8-9 broilers/m² (Thaxton et al., 2006; Onbaşlar et al., 2008; Villagrà et al., 2009; Simitzis et al., 2012; Uzum and Toplu, 2013; Das and Lacin, 2014; Shakeri et al., 2014), while others do not (Türkyilmaz, 2008; Sekeroglu et al., 2011; Houshmand et al., 2012; Cengiz et al., 2015; Arruda et al., 2016). The majority of studies on younger birds (less than 6 weeks old) also find no effect of stocking density on H:L ratio (Heckert et al., 2002; Dozier et al., 2006; Villagrà et al., 2009; Petek et al., 2010), presumably because of their size. Onbaşlar et al. (2008) measured higher levels of serum glucose concentrations in birds maintained at higher densities (12 vs 18 broilers/m²) and Simsek and Ozhan (2015) reported higher serum glucose in flocks of 35,000 birds compared to flocks with only 15,000 birds; however, other studies found no effect of density (Dozier et al., 2006; Thaxton et al., 2006; Houshmand et al., 2012; Abudabos et al., 2013a; Arruda et al., 2016; Qaid et al., 2016). Several authors report higher serum corticosterone concentrations in birds housed at higher stocking densities (Skomorucha et al., 2009; Gomes et al., 2014; Shakeri et al., 2014; Najafi et al., 2015); however, in the majority of studies an association between corticosterone levels and stocking density have not been observed (blood: Dozier et al., 2006; Thaxton et al., 2006; Türkyilmaz, 2008; Houshmand et al., 2012; Cengiz et al., 2015; faecal: Dawkins et al., 2004; Buijs et al., 2009). Decreases in relative weights of the bursa of fabricius (Heckert et al., 2002; Ravindran et al., 2006; Simitzis et al., 2012; Gomes et al., 2014) and spleen (Ravindran et al., 2006) with increasing stocking density suggest stress-induced immunosuppression; however, other authors report no difference in bursa (Onbaşlar et al., 2008; Buijs et al., 2009; Qaid et al., 2016), spleen (Heckert et al., 2002; Onbaşlar et al., 2008; Sekeroglu et al., 2011; Simitzis et al., 2012; Qaid et al., 2016), or adrenal (Thomas et al., 2004) weights.

Additional evidence for high stocking density being physiologically stressful to broiler chickens includes an upregulation in concentrations of ovotransferrin and the acute phase protein α 1-acid glycoprotein (Shakeri et al., 2014; Najafi et al., 2015), an elevation in the expression of heat shock proteins (proteins synthesised under environmental stress) (Beloor et al., 2010; Najafi et al., 2015), and a reduction in telomere length, potentially indicative of damage induced by oxidative stress (Beloor et al., 2010). There is also some limited evidence for high stocking density decreasing developmental stability in broilers. Mirtagioglu et al. (2013) report that relative asymmetry in shank width was greater at a higher stocking density (11 vs 17 broilers/m²), while Ventura et al. (2010) report that tibias obtained from birds maintained at high density (8 vs 18 broilers/m²) were longer and less symmetric in length. Similarly, a composite index of fluctuating asymmetry (an indicator of an animal's ability to cope with its environment), which combined data from 11 measures, was observed to increase with stocking density (Buijs et al., 2012).

A study conducted by Jones et al. (2005a) highlighted that, at least under commercial conditions, stocking density may be less directly impactful upon broiler welfare than poor environmental control. Effective ventilation is paramount to negating the environmental effects of high stocking densities, such as increased humidity and temperature (Jones et al., 2005a; Abudabos et al., 2013b), as well as preventing the deterioration of air and litter quality. The differences in physiological measures between studies, listed above, do not appear to be due to the use of differing density ranges, as the majority of studies utilised similar stocking rates. This suggests that in those studies where no effect of stocking density was found the management protocols of the accommodation were able to cope with the increased number of birds housed. Regardless of whether it is stocking density or environmental factors that are having the greatest impact upon broiler welfare, under commercial conditions, these factors are often interlinked. Therefore, a study that reports an upregulation of a physiological stress response linked to a high stocking density, is likely to be indicative of environmental deficiencies that require addressing simultaneously.

B9.2 Air quality and biosecurity

Effective ventilation is key to maintaining broiler house air quality; without this exposure to high ammonia concentrations can induce eye lesions, immune-suppression, and lower performance, while escalating levels of air-borne pathogens will increase the risk of disease.

Ambient temperature, humidity, airborne gases, particles and microorganisms, in combination with stocking density, ventilation rate, litter quality, age and health status of the birds, interact to determine the air quality in broiler houses. The main sources of aerial pollutants are the feed, the litter and the broilers themselves. The EU Broiler Directive (European Commission, 2007) advises upper limits as follows: 3,000 ppm for carbon dioxide, 20 ppm for ammonia, and 70% for humidity.

The most important role of ventilation is to remove carbon dioxide (CO₂) and water from the air of the house and replace oxygen. CO₂ is a metabolic by-product of the broilers, in combination with litter processes. An increase in CO₂ levels is usually accompanied by increased levels of other detrimental air pollutants such as ammonia, dust and micro-organisms; therefore, CO₂ is commonly used as an air quality indicator.

Ammonia (NH₃) is a colourless gas, produced in the litter by microbial decomposition of the nitrogenous fraction of animal waste. Because there are no legal limits for the exposure of poultry to ammonia, the human limit is used as a default, even though it is based on 8 h of exposure (Jones et al., 2005b). Intensively housed broilers may be chronically exposed to atmospheric ammonia at concentrations >30 ppm in buildings with poor environmental control (Wathes et al., 2002).

Locally, ammonia concentrations are higher in wet areas around drinkers (Miles et al., 2013). Predictably, Jones et al. (2005a) observed lower ammonia levels in broiler houses with fan-assisted ventilation. NH₃ and litter moisture levels have been positively correlated with more leg deformities and HB, and high NH₃ was associated with higher faecal corticosteroid concentrations (Dawkins et al., 2004; Jones et al., 2005a); however, plasma corticosterone and glucose concentrations were not significantly altered by experimental exposure of young broilers to differing levels of ammonia (0–75 ppm) for three weeks post-hatch (Olanrewaju et al., 2008; 2009). Ammonia causes irritation to the respiratory system and the mucous membranes of the eyes, as well as suppressing food intake and growth rate (Kristensen and Wathes, 2000; Homidan et al., 2003). Chronic exposure to NH₃ at 25 and 50 ppm induced corneal eye lesions in broilers after just 7 days (Olanrewaju et al., 2008). Conjunctival lesions have also been positively associated with NH₃ exposure (0–60 ppm). Chronic exposure to high levels of NH₃ has been shown to impair the absorptive and immunological (defensive) function of the small bowel (70 ppm: Wei et al., 2012), trigger chronic hepatic injury (75 ppm: Zhang et al., 2015), suppress immunity (≥ 26 ppm: Wang et al., 2010; 70 ppm: Wei et al., 2015), and stimulate a pro-inflammatory response in broilers (70 ppm: Wei et al., 2015). NH₃ (≥ 50 ppm) inhibits broiler performance levels, and results in lower body weights (Beker et al., 2004; Miles et al., 2004; Yahav, 2004; Wang et al., 2010; Wei et al., 2012) though often with no significant difference in feed conversion ratio (Miles et al., 2004; Wei et al., 2012). NH₃ may also prevent broilers from regulating their body temperature effectively; exposure to ≥ 39 ppm has been shown to increase body temperature to levels typical of mild hyperthermia (Yahav, 2004).

When Miles et al. (2011) measured ammonia emissions from laboratory-prepared litter (mixed with excreta) they observed that sand and vermiculite generated the most NH₃, while wood-shavings and rice hull litters emitted the least. For each litter-type, moisture content was positively associated with NH₃ volatilisation, indicating that litter moisture control is key to reducing NH₃ emissions (Miles et al., 2011).

Airborne particles in poultry houses are almost entirely organic in origin, with bedding, faeces, skin, feathers, feed and micro-organisms contributing to the inhalable and respirable particles (Banhazi et al., 2008). Dust in broiler houses can be minimised through the use of proper ventilation and by keeping relative humidity at recommended levels. Respirable particle concentrations (i.e. that penetrating the unciliated airways) have been found to be: higher in buildings which remained uncleaned between batches of broilers, positively correlated with stocking density, and negatively correlated with ventilation rate and RH (Banhazi et al., 2008). Inhalable particle concentrations have been found to be: lower in tunnel-ventilated buildings (compared to cross-ventilated buildings), higher in buildings utilising straw litter (compared to wood-shavings), positively correlated with temperature and negatively correlated with the building age (Banhazi et al., 2008). The viable airborne particle concentration (i.e. total airborne bacteria) has been found to be: higher in buildings which remained uncleaned between batches of broilers, lower in tunnel-ventilated buildings, negatively correlated with the building age, higher in buildings using wood-shavings as litter, and positively correlated with temperature (Banhazi et al., 2008).

Ozonisation has been used as a disinfectant treatment within the poultry industry with varying success. Ozone is a very unstable and reactive molecule that can rapidly oxidise many organic substances and is often used for odour control. Interest has been expressed in the use of ozonisation in intensive broiler production units to improve air quality, in particular to reduce atmospheric NH₃ levels and bacterial load. Birds exposed to ozone (0.03 ppm) have been observed to grow slower, consume less feed, and have higher mortality and more carcass condemnations than non-exposed broilers (Schwean-Lardner et al., 2009); in addition, ozone caused no significant decrease in ammonia level or total bacterial count. The morbidity and mortality levels in birds subjected to ozone make ozone gas unacceptable for use in a commercial broiler unit.

B9.3 Litter quality

Poor quality litter may result in contact dermatitis, dirty feathers and prevent birds from performing natural litter-based behaviour; litter quality is related to the type of bedding material, nutrition and gut-health, management of ventilation, heating, and water supply (prevention of spillage). Stocking density can contribute towards litter moisture levels, but good quality litter should still be possible with appropriate bird health and environmental management.

The Welfare Quality® assessment protocol for broilers describes a 5-point scale for scoring litter quality (0: Completely dry and flaky, moves easily with foot; 1: Dry but not easy to move with foot; 2: Leaves imprint of foot and will form a ball if compacted, but ball does not stay together well; 3: Sticks to boots and sticks readily in a ball if compacted; 4: Sticks to boots once the cap or compacted crust is broken) (Welfare Quality®, 2009). The measurement of litter pH using a mobile monitoring device may also be useful.

Higher litter moisture has been linked with more drinkers per unit area and with the automatic control of house temperature (Dawkins et al., 2004; Jones et al., 2005a). Bassler et al. (2013) observed a negative correlation between the length of the scotophase and litter quality which reflected reduced bird activity. Broilers generally rest during dark periods, thereby compacting the litter rather than working it. This effect is likely to be more pronounced with increasing bird age, as they become physically less active (Bokkers and Koene, 2003a; Baeza et al., 2012) and produce more faeces. In the Bassler et al. (2013) study, interestingly, FPD and HB were negatively associated with day length, despite deteriorating litter quality.

Season has a marked influence upon litter moisture, which is usually higher during colder months (e.g. Dawkins et al., 2004; Hermans et al., 2006; Meluzzi et al., 2008b). Under cooler ambient temperatures ventilation rates are often reduced to maintain shed temperatures, moisture extraction drops and litter moisture progressively elevates (see B9.4). Hermans et al. (2006) observed that farms using side ventilation systems were at an increased risk of having poor litter quality. In addition, the heating system employed can also contribute to litter deterioration; gas burning heating systems, if located within the shed itself, will generate a lot of water via condensation as a by-product of combustion.

Gut health is linked with litter quality as any increase in faecal water content or diarrhoea (scour) will be directly transferred to the litter. Causes of diarrhoea in broilers include coccidiosis, worms, viral or bacterial infection, a diet too high in protein or long periods without feed. Jacob et al. (2016b) observed an increase in FPD incidence between 19-29 days old, which correlated with the dietary switch to the grower feed; this abrupt dietary transition was hypothesised to have reduced gut health and, thus, litter quality (although this was unreported at the time).

The welfare implications of poor litter quality (high litter moisture) have been described (see B3.4). In addition, contact with wet and dirty litter causes the feathers (particularly those on the breast) to become soiled with faeces such that they lose their protective properties. The scoring system for plumage cleanliness currently in use on-farm as part of the Welfare Quality® Assessment protocol for broilers comprises a 4-point scale developed by Bristol University and utilises photographic images for reference (Figure B4).

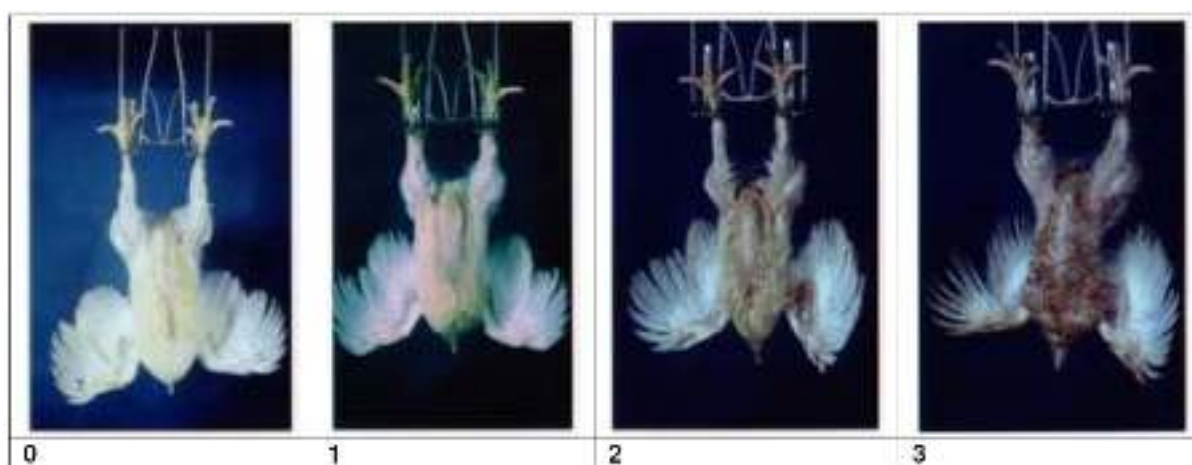


Figure B4: Four point scoring scale (0-3) for categorising plumage cleanliness in broilers (Welfare Quality®, 2009)

Environmental control is the key to managing litter quality. Maintaining the temperature and RH within optimum limits, as well as increasing ventilation levels when necessary, can all be effective in maintaining litter quality. In order to maintain gut health a more gradual change-over between diets may be helpful, and long periods without feed, e.g. caused by feed equipment failures, should be avoided. Strict adherence to biosecurity measures (including separate farm clothing for each house) is also important in preventing wet litter (e.g. Hermans et al., 2006).

B9.4 Temperature and humidity

Maintaining temperature and humidity levels within the limits recommended by the breeder company throughout the life of the broilers is key to maximising welfare; deviations outside of this range are linked with multiple health problems, including mortality.

Broiler breed management guides (e.g. the Ross broiler pocket guide, available from <http://eu.aviagen.com>) generally recommend (whole house) ambient temperature for brooding broilers of between 30 and 33 °C for the first 3 days, depending on relative humidity levels. This is progressively decreased by approximately 3 °C per week until 21 days. Rearing temperatures reflect thermo-neutral conditions (24 °C) and should be maintained for the entire grow-out period.

Air temperature and RH are influenced by environmental conditions, in addition to factors linked to management factors such as heating systems, ventilation rate, stocking density, and live weight of the birds. In addition, RH is also affected by litter type, drinker properties (type and number), water consumption and water spillage. RH is usually higher during colder months when the ventilation rate may be reduced to retain heat within the house and save energy. In UK broiler houses, gas burning space heaters are a common form of heating (Jones et al., 2005a) and this fuel produces a lot of water vapour. Towards the end of the production cycle stocking density has a positive effect upon RH, indicating that environmental control becomes lost as the birds get older (Jones et al., 2005a). High RH will cause litter quality to deteriorate and increase the risk of FPD, an important welfare indicator (see B3.4a).

Adequate ventilation is the most effective method of controlling temperature and RH within the house and increased air-flow can also alleviate the negative effects of high stocking density by removing litter moisture. Following a large commercial field-study, conducted in the UK, Jones et al. (2005a) were able to assign much of the variation in broiler health and welfare to the percentage of time a company could maintain house temperature and RH within limits recommended by the breeder company. High temperature and RH, and the percentage of time these are out of range, adversely affected FPD, gait, leg deformities, mortality, and corticosteroid levels; RH in the first week of life appeared to be particularly important to later health, indicating that better control of humidity during brooding could be key to improving broiler welfare, at least under a Northern European climate (Jones et al., 2005a). The provision of fans (with side inlet ventilation) gave better control over temperature and RH and reduced ammonia levels compared to naturally ventilated systems, indicating more effective air-mixing and flow over the birds (Jones et al., 2005a). Additionally, more variation in RH was recorded in newer houses, possibly because these were larger more open span buildings (Jones et al., 2005a).

The provision of adequate heating during brooding is necessary to maximise chick survival, while adequate ventilation during hotter seasons and in hot climates is necessary to avoid mortality from hyperthermia. Several basic management techniques such as providing insulation, increasing air-flow, reducing bird density and using heat-tolerant breeds, can reduce the risk of heat stress and improve bird welfare. Following a study of UK broiler farms Jones et al. (2005a) report that although the production companies monitored and controlled temperature, with varying degrees of success, none of them monitored or controlled humidity. Considering the negative impact RH can have upon broiler welfare, especially at high stocking densities, implementing the means to measure and control RH within broiler houses could make a significant improvement.

B9.5. Broiler catching

Broilers find manual catching very stressful, most likely associated with being hung in an inverted position; mechanical catching offers the potential for reduced stress and injuries in broilers.

In most countries broilers are currently caught manually; a catcher will carry 2–4 birds in each hand, each bird held inverted by a single leg. This method of catching broilers is a concern as it can cause stress, injury, and even mortality, which has important implications for animal welfare. Queiroz et al. (2015) observed rectal temperature to increase to a temperature above the lower limit of heat stress (41.1 °C) during manual catching, indicating that broilers find this to be a very stressful experience. Pilecco et al. (2012) report that the process of catching is responsible for causing substantially more skin lesions (73%), as seen at slaughter, than the rearing phase (17%). Langkabel et al. (2015) compared two manual catching methods: the 1-leg catching method, and 2-leg catching method (maximum of two birds per hand). Although there was no difference in lesion prevalence between the two techniques, birds demonstrated more behaviours associated with stress (a higher frequency of wing flapping whilst being restrained on the ground, and were more restless after being put into drawers) as a consequence of 2-leg catching; in addition, 2-leg catching took longer and was more difficult and uncomfortable for the workers (Langkabel et al., 2015). Kittelsen et al. (2015a) undertook 607 post-mortems on broilers that had either died during catching procedures on farm or were dead on arrival at the abattoir to examine the separate effects of catching and transport. Lung congestion (37%) and trauma (fractures mainly; 4%) were reasonably common in birds collected from the farm. Lung congestion was likely to have resulted from sudden death syndrome, a cardiovascular disease that is known to be made worse by stressful events. Although catching resulted in few wing fractures (0.8%), the authors noted that it happens earliest in the sequence, so may represent the biggest welfare concern as birds would be in pain for longer (Kittelsen et al., 2015b).

Mechanised catching machines offer the potential to reduce labour costs and damage to the birds, so long as all staff are provided with full training and familiarisation with the machinery prior to depopulation. Mechanically catching broilers with a sweeper-type catching machine under commercial conditions has been found to significantly reduce the number of injuries, especially leg injuries, compared with manual catching (Knierim and Gocke, 2003). Mechanical catching with the CIEMME Super Apollo L harvester induced lower plasma corticosterone concentrations and shorter durations of tonic immobility, and produced fewer wing haemorrhages, compared to manually caught broilers (Delezie et al., 2006). An epidemiological study on a large number of Dutch and German broiler flocks did not find an effect of catching method (mechanical or manual) on the percentage of bruises or corticosterone levels; however, catching company was one of the risk factors for dead-on-arrival birds (Nijdam et al., 2005).

B10. WELFARE CONSIDERATIONS: OVERVIEW

Appropriate incubation conditions (under light), immediate access to food and water at hatch and correct brooding temperatures can all help limit first-week mortality.

The main causes of mortality in older broilers remain metabolic disease and (culling due to) severe lameness; both are a consequence of genetic selection for an excessive mass and unnatural body morphology, and both can, consequently, be selected against. The use of strains with a low tendency for musculoskeletal health problems would help to ensure good

welfare. New slower-growing strains have been developed by breeding companies in recent years, and are increasingly available commercially. In addition, diets that ensure healthy, but not excessive growth rates should be provided.

Lameness is a serious welfare concern. It limits behavioural expression and at least some forms of lameness are associated with pain. Regular assessment of the levels of lameness on farms and the prevalence of contact dermatitis at the slaughterhouse, would allow targets to be set for a progressive reduction in these conditions.

The provision of elevated structures (such as straw bales, platforms with ramp-access, or low barrier-perches) from placement, in combination with an appropriate photoperiod (e.g. 16 hours of light:8 hours of dark at 20 lux) from the second week, should encourage activity and benefit leg health.

Exposure to continuous or near-continuous light causes numerous health issues; low level lighting (<5 lux) is also not appropriate as it has been linked with eye deformities, and broilers are not, generally, at risk of injurious pecking. Appropriate continuous dark periods facilitate rest as well as activity. Vertical mesh panels can be provided to promote a more even distribution of broilers throughout the floor space to further decrease disturbances and facilitate resting.

Sufficient drinkers should be supplied to enable all broilers, even those with limited mobility, to access water at all times, without competition, while the design should prevent spillage onto the litter. Litter should have a small particle-size (e.g. wood-shavings) and be dry and 'friable' throughout the production cycle for the birds' comfort, to preserve leg health and plumage condition, to prevent contact dermatitis and enable dust-bathing and foraging. To maintain litter quality and bird health, appropriate ventilation should be provided year-round and both temperature and humidity should be kept within the range recommended by the breeder companies at all times. Heat stress can be avoided by reducing stocking density and may be mitigated by the provision of cooled perches, while the avoidance of cold ambient temperature is particularly important in reducing the risk of ascites. Exposure to noise levels above 70 dB and ammonia concentrations above 20 ppm should be avoided since broilers find both aversive.

Fast-growing (standard) genotypes are not well suited to extensive systems, even under a restricted dietary regime. Any health benefits of feed restriction are overshadowed by chronic hunger and, thus, extensive systems are only suitable for slower-growing breeds. The welfare of birds of slow-growing strains can be enhanced by the provision of a range area, with lower levels of lameness observed. Planting range areas with shrubs, trees or forage vegetation, providing shelters and maintaining well-drained conditions will help to encourage broilers to move outside and protect against dermatitis.

Broilers can suffer from poor intestinal health (for dietary and infectious reasons), leading to reduced litter quality, and an increased risk of contact dermatitis. The use of prebiotics is a potential solution, given global pressure to avoid antibiotic usage, but further research is required.

The management practice of 'thinning', compromises broiler welfare in several ways. The presence of the catching team is stressful for the flock and this practice poses a substantial biosecurity risk.

Stocking densities of less than 33 kg/m² are associated with reduced lameness, heat stress and contact dermatitis. However, other aspects of the broilers' environment (particularly litter quality and ventilation) may be equally or more important in ensuring good health. Linking limits on stocking density with targets for animal-based measures of lameness and contact dermatitis would be beneficial.

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BROILER BREEDERS

BB1. INTRODUCTION

The primary broiler breeding sector consists of three main genetics companies that breed pedigree (pure line) stock which is kept on extremely high level biosecure farms. Their progeny become the great grandparent and grandparent generations, which in turn produce parent stock hybrids (broiler breeders) which form the main production sector. The majority of broiler breeders are housed under production cycles that comprise two distinct phases within non-cage systems. Chicks are placed in a rearing house at day one, in single-sex groups, where they remain until 18-22 weeks of age (when they get transferred to a production unit). A standard group size during rearing is 2,500-3,000 birds; however, there can be several pens within the same house, totalling approximately 10,000-30,000 birds per house or farm (AHAW, 2010). Males and females are transported to the production farm (or house) at 18-22 weeks, where they are housed together in mixed-sex flocks (at a ratio of approx. 1 male to 9 females) until 60-65 weeks when they are depopulated. The timing of sexual maturation is carefully controlled using photostimulation. Often the male birds will be placed in the production house a couple of days prior to the arrival of the hens. Average flock sizes are 3,000-8,000 birds, and several groups are often kept in the same house (approximately 10,000-30,000 birds per house or farm (AHAW, 2010). During the production phase the hens produce fertile eggs to supply commercial broiler farms. Broiler breeder flocks are not readily accessible for scientific study (outside of the production companies); therefore, relatively little published data exists.

BB2. FEED AND WATER

Chicks are fed a crumb starter diet *ad libitum* until 2-3 weeks of age, then they are either moved onto a second pelleted starter diet or transferred directly onto a grower diet, and the quantity of feed restricted (see BB2.1); between 15-18 weeks they transfer onto a breeder diet and the quantity of feed is increased to sustain the onset of egg production (AHAW, 2010). Males and females follow separate feeding programmes, which is the main reason for housing them separately during rearing. During production they are co-housed and fed using separate feeding systems; males have feeder pans situated at a height that they can access but hens cannot reach, while grills prevent the wider-headed males from accessing the female feed, which is delivered via feed tracks or pans. The maximum feed distribution time for track feeders is recommended to be no more than 3-4 minutes (AHAW, 2010). Spin feeders are also sometime used to deliver feed. Between 0-4 weeks of age 5 cm of feeding (trough) space per bird is recommended, which increases to 10 cm/bird from 5 weeks, and to 15 cm/bird from 10 weeks; during production 10-12 hens/pan and 8 males/pan is recommended (AHAW, 2010). Rapid feed distribution and sufficient trough space should ensure that all birds receive their allocated ration of feed, and minimise the risk of aggressive behaviour and injuries occurring at meal-times.

BB2.1 Feed restriction

Selection for fast growth, high feed intake and high feed conversion negatively impacts upon broiler breeder reproductive success and mortality risk; birds are severely feed restricted to counteract these risks to bird health. In turn, the feed-restriction induces chronic hunger and triggers physiological stress, abnormal behaviour, and frustration of feeding motivation (all alternative forms of reduced welfare).

Owing to selection for fast growth and high breast muscle yields, with consequent high appetite, broiler breeders have a very high *ad libitum* food intake to meet metabolic demands (Heck et al., 2004). If allowed unrestricted feed birds show dramatic increase in bodyweight, and unrestricted feeding increases the risk of several pathological conditions, including lameness, ascites and premature death in broiler breeders, all directly associated with high body mass. In addition, female broiler breeders fed *ad libitum* often experience impaired reproduction, including adverse changes in ovarian function, leading to multiple ovulation and poor fertility (Hocking et al., 2002a). To maintain good health and fertility broiler breeders are routinely provided with severely restricted quantities of feed during both the rearing and laying period. Feed restriction initially delays sexual maturity, but increases reproductive capacity thereafter (Hocking et al., 2002a; Heck et al., 2004). Over the past 30 years optimum broiler breeder body weight targets have remained relatively unchanged, while the growth potential of broilers has steadily increased; the requirement for ever-increasing levels of food restriction continues (Renema et al., 2007).

Feed allocations during rearing are currently about 25-33% of the feed intake of birds fed *ad libitum* and this daily ration is often consumed in, as little as, 15 minutes (de Jong et al., 2002). Feed allocations during the breeding period are generally higher than provided during rearing, varying between 45-80% of the intake of *ad libitum* fed birds of the same age (Bruggeman et al., 1999). Males are less severely restricted than females during rearing, but during the production period males are more severely restricted than females (Renema et al., 2007). Feed is generally delivered as one small daily meal ('daily fed'), but alternative feeding schedules, such as 'skip-a-day', whereby birds get fed twice their daily allocation once every other day, are commonly used in North America and parts of Europe as a means of increasing flock

weight uniformity during rearing. Other skip-a-day programmes commonly used in Europe include 6/1 and 5/2 programmes, whereby birds may receive food for 5 or 6 days within a week and have feed withheld for 1 or 2 (non-consecutive) days. In several European countries, including the UK, Denmark, Sweden and Norway, a daily feeding regime is required as prolonged feed withdrawal is considered negative to welfare; however, Morrissey et al. (2014a) observed little evidence to show that daily feeding was more effective at reducing hunger than skip-a-day regimes when a quantitatively reduced diet is being supplied.

Although feed restriction of broiler breeders counteracts some of the negative side-effects of intensive selection for rapid meat production, there is substantial evidence for negative effects on their welfare. Breeders demonstrate high motivation to eat during the production period (where restriction levels are much lower than during rearing phase); hens will abandon the sitting phase of pre-laying behaviour (an important aspect of nesting behaviour) when feed is provided during nesting (Sheppard and Duncan, 2011). The consequences of severe feed restriction, especially during rear, include: the performance of stereotypic behaviour and over-drinking (BB2.1a), the performance of behaviour indicative of frustration and aggression (BB2.1c), and the upregulation of markers of physiological stress (BB2.1c). The evidence for chronic hunger is indubitable. It should be noted that research on the effects of feed restriction on the welfare of broiler breeders has focused mainly on females; remarkably little work has been done on broiler breeder males and more research is required.

BB2.1a Stereotypic behaviour and over-drinking

Restricted-fed broiler breeders are more active (they spend less time resting and more time foraging in the litter) and display high rates of stereotyped oral behaviour and pacing than birds fed *ad libitum* (Savory and Lariviere, 2000; Hocking et al., 2001; Kubikova et al., 2001; de Jong et al., 2002; 2005a; Merlet et al., 2005). Resting was significantly lower in standard birds fed a restricted diet than in those fed a semi-restricted diet, or slow-grow birds fed *ad libitum*, indicating that activity is correlated to the food allowance and, thus, indicative of hunger (Jones et al., 2004). Stereotypic pecking or 'spot pecking' (directed at the empty feeder, litter, drinker, pen walls or at other birds) is commonly observed after feeding (De Jong et al., 2002; Hocking et al., 2002b), and this increases with the level of restriction (Savory and Lariviere, 2000; Merlet et al., 2005; Sandilands et al., 2005). Birds that were feed-restricted after peak-of-lay performed more stereotypic pecking at non-feed objects compared with birds fed *ad libitum*, although this increase was much less than that performed by birds feed-restricted during rearing (Hocking et al., 2002b). Stereotypic behaviour is associated with opioid release and is considered to be de-arousing (Savory et al., 1992); it is hypothesised that the performance of stereotypic behaviour may represent a coping strategy for alleviating stress, in this case it is thought to denote hunger and represent frustration due to an unfulfilled feeding motivation (de Jong et al., 2002; 2005a).

Over-drinking (polydipsia) is commonly observed in feed-restricted broiler breeders (Hocking et al., 2001; de Jong et al., 2002; Jones et al., 2004) and, consequently, water intake is often restricted in order to maintain litter quality. However, Jones et al. (2004) observed that although restricted-fed standard birds performed more drinking behaviour than a slow-grow breed fed *ad libitum*, they had similar dry weights of digesta in each section of the gut (except the crop); this suggests that drinker-directed activity might be a substitute for foraging (providing an outlet for the motivation to perform appetitive and consummatory behaviour) rather than an attempt to increase gut fill.

BB2.1b Inter-bird pecking

In broiler breeders, the restriction of food can trigger resource competition and aggression. The delivery of restricted 'meals' during rearing causes increased feeding competition. Aggressive pecking, triggered by competition at the feeder, is prevalent amongst feed-restricted males and females (Hocking et al., 2004; Jones et al., 2004; Hocking and Jones, 2006; De Jong and Guémené, 2011), and is thought to be associated with hunger. Aggression at the feeder, as well as non-aggressive competition for food, may lead to minor skin damage (e.g. scratches) and possible infection. In addition, control 'daily-fed' birds displayed more object pecking and aggression than 'skip-a-day' fed birds, which may imply that having a larger volume of food less frequently improves welfare (Morrissey et al., 2014a).

Feather pecking can also occur in broiler breeders but it seems to have a closer relationship with aggressive behaviour than in laying hens with *ad libitum* feed. Morrissey et al. (2014a) observed feather pecking to occur at higher frequencies in birds fed a control (quantitatively restricted) diet, especially after feeding bouts, than in birds fed a high fibre diet in combination with an appetite suppressant. Hocking et al. (2004) reported lower levels of skin damage and cannibalism in birds given restricted diets supplemented with fibre (sugar beet) than in those receiving restricted control diets.

BB2.1c Physiological markers of stress

Elevated baseline plasma corticosterone concentrations are observed in feed-restricted broiler breeders during rear compared to birds fed *ad libitum* (Hocking et al., 2001; Kubíková et al., 2001; de Jong et al., 2002; 2003; Rajman et al., 2006); a restriction level of more than 50% appears to trigger this response. De Jong et al. (2003) observed a positive relationship between the level of feed restriction and plasma corticosterone concentration. In addition, the restricted fed birds demonstrated an elevated corticosterone response to an acute stressor (5 minutes restraint) (de Jong et al., 2002). Although these results appear to indicate that the restricted broiler breeders are chronically psychologically stressed (i.e.

are experiencing feelings of hunger or frustration) compared to *ad libitum* fed birds, corticosterone upregulation is also likely to reflect metabolic stress arising as a direct consequence of food restriction since corticosterone has a key role in energy homeostasis and the regulation of blood glucose levels (de Jong et al., 2002).

The use of white blood cells as a sensitive indicator of chronic stress associated with food restriction has come under question, as although H:L ratios have been observed to increase following prolonged food removal (Altan et al., 2005), and following feed restriction (Hocking et al., 2001; de Jong et al., 2003; Jones et al., 2004), increased H:L ratios are not always observed in feed restriction studies (e.g. de Jong et al., 2002; Sandilands et al., 2006). It may be that this particular index of stress is not a sensitive enough measure of hunger, unless there are also extreme differences in body weight (Hocking et al., 2001).

BB2.2 Measuring hunger

Although a definitive means of quantifying hunger has yet to be developed the measurement of 'compensatory feed intake' appears to correlate well with the level of feed restriction, and feed restricted broiler breeders have been shown to work for the chance to perform exploratory and foraging behaviour (the appetitive phase of feeding) in the absence of a food reward.

Hunger is a subjective state and therefore difficult to monitor or quantify; a reliable definitive indicator of hunger does not yet exist. Behavioural estimators of hunger in current use include those thought to be indicative of frustration (pecking at non-food objects, increased general activity and aggression, excessive drinking, and increased feather pecking), while behaviours considered to be indicative of increased satiety (or reduced hunger) include: increased time spent dust bathing, preening, and resting (i.e. comfort behaviours). Physiological measures of stress (e.g. corticosterone levels and H:L ratios) are used to monitor the impact of dietary compositions or modified feeding regimes, yet are likely to be confounded by metabolic influences (e.g. de Jong et al., 2002; 2003). A test of feed motivation has been developed that appears to provide a good index of hunger in broiler breeder pullets. De Jong et al. (2003) demonstrated that compensatory feed intake (calculated by allowing birds that had previously been feed-restricted unrestricted access to food) on day 2 of the test was linearly related to the birds' previous level of restriction (25-100% *ad libitum* feed intake). They also determined that the relative compensatory feed intake (feed intake/g metabolic weight) was three times higher in pullets fed a commercial restriction programme than that of birds fed *ad libitum* (de Jong et al., 2003). Nielsen et al. (2011) developed a 'Novel Food Test' to investigate the conflict between fear (neophobia) and hunger levels by presenting breeders with a novel food in a novel trough. Dixon et al. (2014) report that feed restricted broiler breeders would work (traverse a water-filled runway to access a wood-shaving covered platform) for the chance to perform exploratory and foraging behaviour (the appetitive phase of feeding) in the absence of a food reward; the most severely feed-restricted control birds (receiving commercial restriction levels) made more successful crossings and crossed quicker than less severely restricted birds. The high level of foraging motivation, even in the absence of food, provides additional evidence for commercial restriction levels inducing chronic hunger in broiler breeders. Buckley et al. (2015) aimed to validate the use of state-dependent learning (SDL) as a novel welfare assessment tool to evaluate the hunger state of feed-restricted broiler breeders but reported limited evidence of an SDL preference between birds supplied alternatively with quantitative feed restriction and *ad libitum* access to the same feed.

BB2.3 Alternatives to feed restriction

Alternative feeding strategies (such as diet dilution and the use of appetite suppressants) do not clearly benefit breeder welfare, nor are they 'preferred' by the birds; although the inclusion of a high proportion of insoluble fibre may temporarily alleviate the physical sensation of hunger during rearing these diets do not fulfil long-term metabolic requirements. Genetic solutions are required since current breeding goals are unsustainable; the use of 'dwarf' genotypes reduces the need for feed restriction.

BB2.3a Use of different genotypes

One possible alternative to feed restriction, to improve welfare, is to use breeder genotypes that can be fed *ad libitum*, or that require less feed restriction, and still maintain acceptable production (Jones et al., 2004; Decuyper et al., 2006). Slower growing chickens, such as "Label Rouge" breeders can be fed *ad libitum* with excellent reproductive results. However, their offspring (broilers) have a lower feed efficiency and take twice as long to reach market weight than offspring from standard fast-growing broiler breeders; so, to be economically viable, they demand a higher retail price (Puterflam et al., 2006). These slow-grow breeders can be crossed with standard male breeders to produce offspring with a grow-out period only 1-2 weeks more than standard birds (Puterflam et al., 2006); however, the standard males will still require feed restriction. A dwarf genotype of broiler breeder (with a body mass two thirds that of a standard breeder) also exists; these can be fed low energy diets *ad libitum* (i.e. receive qualitative food restriction) and achieve reproductive capabilities similar to standard feed-restricted breeders, and produce offspring with a growth period extended by only a few days (Heck et al., 2004; Decuyper et al., 2006). Jones et al. (2004) observed qualitatively restricted dwarf breeders to perform less stereotypic ('drinker-directed') behaviour than quantitatively restricted standard breeders. Since a genetic

component exists regarding the degree of restriction necessary, it is recommended that birds requiring less feed restriction should be selected as future breeders even if this may involve a reduction in selection pressure for high growth rates.

BB2.3b Alternative feeding strategies: qualitative restriction

Several different management strategies have been applied in an attempt to reduce the negative effects of feed restriction (hunger) in broiler breeders while maintaining the suppression of growth. These broadly include dietary manipulations; especially the use of non-nutritive fillers to reduce the diet quality (i.e. low protein or high fibre) and/or the inclusion of appetite suppressants, as well as the modification of feeding programmes. Almost all of the work on animal-based indicators of welfare relating to feed restriction has been carried out under experimental conditions.

Feeding greater quantities of lower-density diets are thought to promote physical satiety, since larger feed rations increase gastrointestinal filling. Low-density and high-fibre diets increase feeding time and appear to reduce feeding frustration (less stereotypic object pecking) and hunger (compensatory feed intake was reduced) compared to quantitatively restricted diets (Hocking et al., 2001; 2004; de Jong et al., 2005b; Nielsen et al., 2011; Moradi et al., 2013; Van Emous et al., 2014; 2015a; 2015b). Dietary fibre type appears important. The inclusion of high levels of insoluble fibre during the rearing period can reduce levels of injurious pecking and stereotypic pecking (i.e. negative welfare indicators), and increase dust-bathing, comfort behaviour and foraging (positive welfare indicators), compared to that observed under a control diet (Hocking et al., 2004; Sandilands et al., 2006; Nielsen et al., 2011). The possibility of an increased food allowance with a diluted diet, in combination with rewarded foraging behaviour, may relieve some of the frustration associated with restricted feeding. Hocking et al. (2004) also observed a reduction in stereotypic pecking under a diet containing a low proportion of soluble fibre (sugar beet pulp), the high water holding capacity of which was hypothesised to (temporarily) increase the sense of satiety; however, Nielsen et al. (2011) observed that breeders fed a high proportion of soluble fibre displayed behavioural signs of intestinal discomfort (including prolonged standing with their necks retracted) and had degraded litter (see BB8.3).

Other studies found qualitative restriction to have no effect upon behavioural indexes of welfare (Savory and Lariviere 2000; Hocking, 2006). Savory and Lariviere (2000) observed that feeding motivation (determined using operant testing) and activity levels (likely to be indicative of hunger) were not altered following the provision of qualitatively restricted diets (achieved via dilution and appetite suppression) provided *ad libitum*. The birds appeared to have a similarly high motivation to feed as birds placed on quantitative restriction, and presumably they still experienced hunger. In addition, *ad libitum* access to high-fibre diets produced higher growth rates than anticipated, indicating that some quantitative restriction is still required in addition to diet dilution (Savory and Lariviere, 2000). Interestingly, Hocking et al. (2001) observed that (quantitative and qualitative) feed restricted birds were less fearful (assessed using tonic immobility) than birds fed *ad libitum*.

Use of an appetite suppressant (calcium propionate, CaP) and/or a diet diluent (oat hulls) during the rearing period has been successful in controlling growth rate and stereotypic pecking, and reducing feeding motivation (rate of eating), compared to a control group fed a quantitatively restricted diet (Sandilands et al., 2005; 2006); however, as physiological indices of stress and activity levels did not differ between treatments it may indicate that the birds found the food unpleasant in some way (disagreeable taste or produced intestinal discomfort), rather than it producing a rewarding sensation of satiety. Morrissey et al. (2014a) observed a reduction in several behavioural indices of hunger (including increased resting time and decreases in feather pecking, object pecking and aggression), suggesting that a high-fibre diet, including CaP, can improve certain aspects of breeder welfare.

Hocking et al. (2001) observed the H:L ratio to be higher in quantitatively restricted breeders at 6 weeks and lower at 24 weeks compared with birds fed *ad libitum*; this suggests that both feed suppression in young birds (with a high metabolic rate during the phase of high growth), and the consequences of additional body mass in older *ad libitum* fed birds, are both stressful and, thus, both associated with low welfare. De Jong et al. (2005b) observed lower H:L ratios in birds fed an increased volume of low density restricted diets during the production phase (lay) compared to birds fed a standard restricted diet, indicating that the increased meal size lowers stress; although no difference was observed during rear (Jones et al., 2004; Hocking, 2006). Plasma corticosterone concentrations are elevated in breeder hens subjected to qualitative, as well as quantitative, food restriction, compared to unrestricted control diets during the rearing or laying period (Hocking et al., 2001; Kubíková et al., 2001; de Jong et al., 2005b; Sandilands et al., 2005). Sandilands et al. (2006) observed similar plasma corticosterone levels in quantitatively or qualitatively food restricted birds that achieved at least commercial target weight, while higher levels were associated with a treatment that produced above target growth suppression. This provides further evidence for corticosterone reflecting a direct metabolic effect of feed restriction (calorific stress), independent of feeding method or food allowance. Lower corticosterone concentrations have been observed in birds fed diluted diets high in fibre (Moradi et al., 2013) and low in protein (Hocking et al., 2001) compared to quantitatively restricted control diets, although the latter observation was not replicated in later studies (Hocking, 2006; Van Emous et al., 2014).

A series of recent studies have failed to develop behavioural tests to determine the preference of broiler breeders for different diets. Following the inability of a T-maze task to conclusively assess the dietary preference of broiler breeders between a quantitative (control) or qualitative (CaP: 3 g/kg; oat hulls: 300 g/kg) restricted diet, Buckley et al. (2011a) concluded that this outcome was likely to reflect task learning failure and not necessarily a lack of dietary preference. Consequently, Buckley et al. (2011b) provided evidence for hunger (associated with feed restriction) to impair learning; feed restriction significantly reduced performance in a discrimination task (ability to associate colour cues with differences in a food quantity reward). The authors conclude that Y-maze choice tests are not an appropriate methodology for determining hungry broiler breeder dietary preferences, especially since some of the less severely feed-restricted birds also struggled to learn this task (Buckley et al., 2011b). Buckley et al. (2012) successfully used a place preference task to demonstrate that broilers (as a model for broiler breeders) had a significant preference for an environment associated with *ad libitum* food (as opposed to an environment associated with quantitative feed restriction); however, this outcome was reliant upon a state-dependent effect, as it was only true when the birds were tested hungry. No preference was evident between environments associated with either a quantitative ration or a quality-adjusted diet (quantitative ration supplemented with a hunger suppressant); an absence of preference could have arisen because the net effect, in terms of affective state, may have been perceived as similar between environments (e.g. the control environment may have offered a more palatable diet than that containing the hunger suppressant, yet resulted in higher levels of hunger) (Buckley et al., 2012). Overall, the evidence suggests that qualitative restriction methods do not conclusively benefit breeder welfare.

BB2.3c Alternative feeding strategies: feeding management

A high growth pattern (i.e. rearing breeders to a higher 20-week bodyweight than that recommended by breeding companies) is seen to increase feed intake and eating time, but did not appear to improve bird welfare (i.e. did not reduce stereotypic object pecking) (Van Emous et al., 2013). Altering the feeding management programme to increase feeding time, including scattered feeding and the provision of two meals per day (either in the litter or in a trough), did not reduce behavioural or physiological indicators of hunger (compensatory feed intake), frustration (general activity) or stress (plasma corticosterone) (de Jong et al., 2005a). Scattered feeding reduced the time breeders spent object pecking and increased the time spent foraging, while birds fed two meals a day walked more, which may indicate food searching-related activity or frustration of the feeding motivation (de Jong et al., 2005a). Scatter feeding a diet with a high ratio of insoluble fibre did appear to alleviate the sensation of hunger and improve welfare in breeders during rearing, including increased foraging, dust bathing and comfort behaviours, and reduced tail pecking and stereotypic pecking (Nielsen et al., 2011); the combination of increased food allowance and rewarded foraging behaviour in this study appeared beneficial in reducing feeding frustration. A step-up lighting programme (11-16 h over 10 weeks) and feeding a mash diet, instead of pellets, have both been found to reduce the rate of feed consumption; feeding breeders pellets is not advised as it increases time available to spend on stereotypical behaviour (Gous and Danisman, 2016).

The apparent impossibility of achieving optimal production requirements for broiler breeders (high reproductive performance, good health and low mortality) without resorting to severe feed restriction (and impaired welfare), has been termed the 'Broiler Breeder Paradox' (Decuyper et al., 2006). It is clear that nutritional strategies, although sometimes helpful in alleviating adverse behaviour associated with hunger, do not fulfil long-term metabolic requirements and are not sustainable since current breeding goals remain on an upwards trajectory (towards ever better feed conversion and increased breast meat).

BB2.3 Water

Access to water is often restricted to preserve litter quality; however, this may have additional welfare implications for broiler breeders by creating prolonged periods of thirst, as well as hunger.

In temperate climates drinker recommendations are generally 8-10 birds/nipple, 15 birds/cup or 60-80 birds/bell drinker (1.5-2.5 cm/bird); more space will be required in hotter climates (AHAW, 2010). During the first few weeks chicks usually have *ad libitum* access to water, however, limiting access to water is common management practice in some countries during the rear and production periods when it may only be available for a couple of hours around feeding time, and possibly at other times in the day (e.g. one hour in the evening prior to lights out). Although water is restricted to conserve litter quality, i.e. to prevent excessive water spillage from stereotypic drinker manipulations and to avoid excessive drinking (Hocking et al., 1993), this is likely to create extended periods of thirst. In some systems the drinkers are located on the slats, which should limit litter damage from water spillage. Freedom of (prolonged) thirst is of paramount importance for animal welfare yet animal-based measures of thirst are currently absent from animal welfare monitoring schemes due to the difficulties associated with quantifying a subjective state. Voluntary water consumption over time may offer a potential means of assessing thirst in broilers on-farm as it has been shown to increase with the length of water deprivation (see B2.8). Although the consequences of water withdrawal on breeder welfare have not yet been studied it is obvious that water restriction should not be employed under warmer climates. In addition, it is important that water access is not too restricted as water consumption is an important means of automatically monitoring flock health.

BB3. RISK MANAGEMENT

BB3.1 Mortality

The majority of mortality in broiler breeder flocks occurs as a result of focused culling for particular selection criteria throughout the production cycle; males are subject to heavier culls, while dwarf breeds appear to display an improved viability. Mortality during the production phase is high, particularly for male birds.

BB3.1a Focused culling

At the hatchery, poor quality (rejected) chicks are separated from good quality chicks, and culled, commonly using CO₂ gas or instantaneous mechanical destruction. The good quality chicks are then sexed and the female chicks from the female line, and the male chicks from the male line, are transferred to the rearing farm as breeder (and grandparent) stock; the male chicks from the female line and female chicks from the male line go off to be reared separately for meat as standard broilers. Focused culling occurs during the rearing period, e.g., to correct sexing errors (estimated at 1-2%), and to remove any runts, or individuals with leg problems or post-trimming beak deformities (AHAW, 2010). Selection continues throughout the production period. Approximately 15-25% of males will be culled due to low reproductive activity, extreme body weight and poor leg condition, while the culling of hens is much lower, approximately 1-2% (AHAW, 2010).

BB3.1b Total mortality

Due to continuous selection over the last few decades natural mortality levels in grandparent and breeder lines have undergone a decline and hatching egg production has increased (Hocking and McCorquodale, 2008). The expected mortality during rearing (i.e. from day-old until they are transferred at 16-21 weeks), including culling, is approximately 5-7% for females (5% for dwarf females) and 8% for males (AHAW, 2010). During the production phase total male mortality, including culls is about 25-35%, while total female mortality varies between 4-14% (6-7% for dwarf females) (Hocking and McCorquodale, 2008; AHAW, 2010). Mortality in grandparent lines ranges between 10-13% (Hocking and McCorquodale, 2008); this is fairly high due to rigorous selection criteria. A recent study reported normal mortality rates of 22.4% and 13.9% respectively on two broiler breeder farms in the Netherlands (Landman and van Eck, 2015). These figures, particularly for male birds are high in comparison with mortality rates seen in broiler and laying hen flocks (see B3.1 and LH3.1).

BB3.2 Causes of mortality

Injuries resulting from aggressive (sexual and non-sexual) interactions are likely to contribute to mortality in some flocks, but leg problems and infectious disease appear to be managed well; there is little data on specific mortality issues in broiler breeders.

As seen in section BB3.1, the majority of mortalities in restricted-fed breeder flocks can be attributed to focused culling. In a study by Heck et al. (2004) mortality was dramatically increased in broiler breeder females fed *ad libitum* (approximately 40%) at 40-49 weeks of age, compared to approximately 6% in restricted fed hens. High mortality in breeders fed *ad libitum* is largely related to culling for lameness; however, leg weakness problems are not commonly observed in broiler breeders due to the management of growth via feed restriction. Peritonitis is a fairly common reproductive disorder that can be fatal if not treated with antibiotics. Although the cause is unknown, it is thought to be related to immunosuppression following the rapid rise in plasma oestrogen at the onset of lay and subsequent *Escherichia coli* and viral infections (Hocking and Bernard 2000). Metabolic disorders such as sudden death syndrome are occasionally observed in breeder hens. Infectious disease, in general, is not a major cause of mortality in broiler breeders or grandparent lines (see BB3.10). As the maintenance of a high health status is critical (for the grandparents and breeders themselves, and their offspring), rigorous biosecurity measures, intensive vaccination programmes and health monitoring are standard. The uptake of food and water are usually constantly monitored to provide an early warning of possible disease. There are fewer restrictions for medicating breeder flocks than for laying hens, since no withdrawal periods are required for hatching eggs in regard to consumer protection; this enables wider use of antibiotics.

Male aggression during mating can inflict severe skin lesions on females which may prove fatal (see BB3.6), especially if they become infected; not mutilating males (see BB8.4a and 8.4b) would, therefore, likely lead to higher female mortality. When female breeders were provided with a greater feeder space allowance during lay (as occurs commercially in the USA) greater mortality (and lower egg production) was observed than seen in birds which had access to the larger feeder allowance throughout both rear and lay (Leksrisompong et al., 2014). As most fatalities occurred early in the production period this mortality may have resulted from more pronounced social assertions within the flock, i.e. more aggressive pullets occupying the extra feeder space when it became available, drastically reducing feed availability for less dominant hens and causing them stress (Leksrisompong et al., 2014).

Presumably breeders are more susceptible to the effects of nutrient malabsorption, (e.g. vitamin D, calcium, and phosphorus deficiencies following intestinal disease), or inadequate nutrition (e.g. as a result of dietary errors) due to their

qualitatively restricted diets. Ekmay et al. (2012) observed that reducing dietary nonphytate phosphorus to 0.15% (compared to 0.40%) reduced skeletal quality and increased breeder mortality. Although uncommon, commercial breeders can experience mortality because of impactions of the digestive tract, ultimately leading to starvation or traumatic digestive lesions, as a result of litter-eating; many factors can prompt poultry to eat litter, including over-crowding, systemic toxins, fibre or vitamin deficiencies, limited feed or feed access, parasitism, transfer of birds into unfamiliar surroundings, or changes in feeding regimens (Roza et al., 2006).

BB3.3 Musculoskeletal disorders (lameness)

Leg disorders are generally associated with high growth rates and high body mass, both of which are controlled in broiler breeders by restrictive feeding regimes; no data on lameness in modern breeders is available.

Data on health issues, such as leg disorders, are not systematically collected for broiler breeders, so their prevalence is not known. Although the same musculoskeletal lesions that are commonplace in broilers (including tibial dyschondroplasia, femoral head necrosis, bone deformities, ligament and tendon rupture, see B3.3) have also been reported in broiler breeders (AHAW, 2010), modern breeders generally display good leg health due to feed restriction. Tendon rupture is a non-infectious disorder that can cause lameness in 1-5% of breeder hens within a flock, usually between 23-35 weeks of life; there is no treatment and birds are culled as soon as possible (AHAW, 2010). Crespo and Shivaprasad (2011) hypothesise that a cause of gastrocnemius tendon rupture could be aggression (and presumably increased forced matings) following the introduction ('spike') of new males into the flock (see BB8.4e). Lameness in broilers is usually assessed by standardised gait scoring systems (see B3.3d) and similar methodologies could be applied to assess leg weakness in breeders.

BB3.4 Bone strength and osteoporosis

High egg production may negatively impact upon bone (femur) mass density in broiler breeder hens; no data on osteoporosis in modern breeders is available.

Very little research has been conducted on bone strength in broiler breeders and no data on prevalence of osteoporosis in breeder hens is available; although, as breeder hens demonstrate high rates of egg production, osteoporosis is likely to occur within older flocks. Almeida-Paz et al. (2006) observed egg production to have little influence on bone mineral density (BMD) in broiler breeders producing at a lower rate than occurs under commercial conditions. BMD values in breeders were higher than values previously reported in broilers and increased with age, until 30 weeks when birds started to lay; a 9% increase in egg production at 47 weeks was associated with a significant decrease in femur BMD, which may indicate that this bone is responsible for calcium (Ca) supply for eggshell formation, when needed (Almeida-Paz et al., 2006).

Broiler breeder pullets fed *ad libitum* were found to have greater bone dimensions and breaking strength than feed-restricted birds; however, their bones required less stress to break which is indicative of lower mineralisation (Moreki et al., 2011). According to bone length and breaking strength values, bone development of feed-restricted breeder pullets becomes fixed at 12 weeks of age (Moreki et al., 2011). Dietary Ca (range: 1-2%) had little effect on bone formation in feed-restricted breeder pullets up until 18 weeks of age, although bone breaking strength was positively associated with the percentage of dietary Ca; increasing levels of dietary Ca above 1% does not appear to optimise bone formation in feed-restricted breeders during rear (Moreki et al., 2011).

BB3.5 Injurious (severe) feather pecking

Injurious feather pecking is a welfare issue directly associated with feed restriction in broiler breeders; further research is needed: (a) to reduce hunger experienced by modern breeders, and (b) to develop commercially viable environmental enrichment for inclusion within breeder houses.

Good feather cover protects females from skin damage caused by rough mating behaviour (see BB3.6); however, during the reproductive phase breeder hens often display skin lesions as a result of feather pecking (Millman et al., 2000). Feed restriction causes welfare problems associated with hunger and leads to increased competition around feeding time. Pereira et al. (2007) observed breeders to perform more chasing and feather pecking in the morning, following feeding. Feather pecking appears to be improved via dietary manipulation (see BB2.3b). Experimental qualitatively restricted diets (containing the appetite suppressant CaP and diluted with soybean hulls) were associated with better feather condition than a control (quantitatively restricted) diet, indicating that these alternative diets reduce stereotypic feather pecking and increase satiety (Morrissey et al., 2014b). In addition, breeders fed on a skip-a-day basis had better feather scores than daily-fed birds, indicating a reduction in stereotypic feather pecking under the former feeding regime (Morrissey et al., 2014b). Van Emous et al. (2014; 2015b) report that the provision of breeder pullets with a low protein diet during rearing increased feather pecking (as reflected by a reduction in feather cover).

Laying hens are often provided with environmental enrichment, such as pecking devices, mirrors, balls, string, or bales of straw or wood shavings, with the aim of reducing the incidence of adverse behaviour such as injurious pecking, cannibalism and aggression (see LH3.5). In general, commercial broiler breeder farms do not use any environmental

enrichment during rearing or production. In one study breeders were not observed to pay much attention to bunches of string but appeared to find bales of wood-shavings attractive; however, neither form of enrichment reduced feather damage or adverse behaviour associated with feed restriction, including aggression (Hocking and Jones, 2006). More injurious feather pecking (severe feather pecks and feather pulls) has been reported in broiler breeders kept entirely on slats than in birds housed on litter; this suggests that the availability of good quality litter for foraging diminishes the effects of stress associated with feed restriction, and that this undesirable behaviour will be minimised if good litter conditions are maintained (Hocking et al., 2005). Breeder males display significantly more aggression (both male-to-male and non-sexual male-to-female) than layer strain males; this general aggressiveness appears to be associated with genetic differences in breeders, rather than arising as a consequence of feed restriction (Millman and Duncan, 2000a; Millman et al., 2000). Increased aggression between males should be anticipated in flocks that have been spiked (see BB8.4e).

BB3.6 Sexual aggression

Sexual aggression poses a severe problem as it directly reduces female welfare and indirectly compromises male welfare due to the requirement for 'preventative' mutilations; ideally this trait should be selected against in breeding programmes, but simple remedial actions such as the provision of alternative lighting or mesh panels within the breeder house (to increase environmental complexity), may be beneficial in the short-term.

Broiler breeders are commonly reared separately under commercial conditions and then brought together at 20 weeks of age; soon after mixing males demonstrate high levels of aggression towards females in both a sexual and non-sexual context and this increases during early lay (de Jong et al., 2009). Males and females generally become sexually mature between 18-23 weeks of age. Inadequate (lighting) management may lead to male breeders reaching sexual maturity earlier than females; this can lead to forced copulations, resulting in distress and injury in the females (Leone and Estevez, 2008). It is important that males and females are equally mature at introduction to reduce the risk of females being over-mated or the occurrence of extreme aggression towards females or inactive males; for this reason immature males should not be transferred into an established production house (AHAW, 2010). However, even when both sexes mature at a similar time breeder males still display high levels of female-directed aggression, principally during the performance of sexual behaviour. Sexual behaviour of males is generally described as rough, with males chasing and pecking females, pulling their combs and often forcing copulation; courtship behaviour is usually absent (Jones and Prescott, 2000; Millman and Duncan, 2000a; 2000b; Millman et al., 2000; Jones et al., 2001; de Jong et al., 2009). Breeder males display significantly less courtship behaviour than layer-strain males (Millman and Duncan, 2000b; Millman et al., 2000). As a result of rough sexual behaviour females may have severe skin lacerations to the back of their heads and necks where males peck and grab them with their beaks, as well as under their wings and on their body where the male's claws rip the skin during forced mounts (Millman and Duncan, 2000a; Millman et al., 2000; Jones et al., 2001; de Jong et al., 2009; Moyle et al., 2010). Preventive measures, in the form of male mutilations, are commonly performed (see BB8.4a and 8.4b).

Females will huddle, stand alert, and alarm call in pens with high levels of male aggression (Millman et al., 2000); females often remain on the raised slatted area or within the nests, while the males spend most of their time upon the litter area (Leone and Estevez, 2008). A study that initially assumed females with less feathering on their backs to have been subject to more frequent matings actually observed that these females received fewer mounts and completed fewer matings; there was a trend for more male aggression towards females with less back feathering, which may have been a response to frustration following sexual rejection by the hens, or an attempt to intimidate the hens into mating (Moyle et al., 2010). Female breeders often fail to perform 'normal' responses following a male approach; instead of crouching they will often not respond, then struggle or attempt to escape from the male during mating (Jones et al., 2001; de Jong et al., 2009). It is hypothesised that deficiencies in courtship behaviour may play a part in this female rejection (Jones et al., 2001). Although McGary et al. (2003) observed a decline in forced mating behaviour with age (30-51 weeks), as would be expected if the hens became habituated to the males' sexual advances, the same was not observed in younger breeders (20-28 weeks: de Jong et al., 2009). Sexual aggressiveness does not appear to be a consequence of feed restriction (Millman and Duncan, 2000a; 2000b); however, it does appear to be triggered by female evasive behaviour (Moyle et al., 2010) and there may be a genetic component (Millman and Duncan, 2000b). As such, mating aggressiveness could be one of the selection points for breeders, since this trait is likely to be linked to fertility (AHAW, 2010).

Separate sex rearing, large group sizes, and high stocking density may also play a role in impeding the development and recognition of sexual behaviour, in turn, decreasing the likelihood of receiving an appropriate response from the other sex (de Jong et al., 2009). Mating behaviour is improved (increased courtship behaviour and more completed matings) when broiler breeders are housed at low stocking density during production (see BB8.1). Leone and Estevez (2008) report that the provision of vertical panels within the central litter area improved overall reproductive performance in broiler breeders; the panels attracted females to the litter floor, thereby decreasing male-male competition for females and over-mating. Presumably the cover afforded by these panels would also provide a means by which females could avoid the attention of certain males. Jones et al. (2001) demonstrated that UV_A light (320< λ <400 nm) increased mating behaviour, and the proportion of successful matings in broiler breeders; the authors conclude that UV_A is clearly implicated in the transmission of sexual signals and, as such, may have welfare implications. A further increase in forced copulations should be anticipated in flocks that have been spiked (see BB8.4e).

There is a pressing need for animal-based welfare outcome indicators relating to feather and injury scoring to be developed and used to assess the level of damage related to aggression during mating (see BB3.6), feed competition (see BB3.5) and following spiking (see BB8.4e) in broiler breeders. Although focal observations of aggressive interactions are not feasible on farm several scoring systems have already been developed for use in laying hens which could be adapted for use in breeders.

BB3.7 Feather loss

Feather loss arising from frequent mating reduces the hen's ability to efficiently maintain her body temperature and leaves her more at risk of sustaining skin damage from subsequent matings.

Feather cover quality differs with genotype (Özkan et al., 2002). From the second half of the laying period onwards, the feather cover of the female breeders often deteriorates due to feather pecking and (predominantly) mating behaviour; this creates a welfare issue as it reduces the capacity for efficient thermal regulation and increases the risk of obtaining skin damage (AHAW, 2010). Renema et al. (2007) observed that the heaviest hens (at the end of the production cycle) had the best feather cover, suggesting that hens with lower body weight were mated more.

BB3.8 Leg and foot health

Although contact dermatitis, especially foot pad dermatitis (FPD), does occur in a severe form in broiler breeders and, thus, poses a significant welfare concern, this pathology has received little attention from the scientific community and its prevalence is not currently known; in breeders FPD is likely to arise as a result of poor litter quality, slat characteristics and slat usage.

BB3.8a Foot pad dermatitis

Foot pad dermatitis (FPD), or pododermatitis, is a skin condition of the feet associated with prolonged contact with irritating material. It occurs on the plantar surface of the foot, most commonly on the central pad, but it can also affect the skin of the toes. FPD can range in severity from mild skin discolouration and superficial erosions to inflammatory reactions of the subcutaneous tissue, and deep necrotic lesions. FPD is a common welfare issue for commercial broilers, associated with poor litter quality (high moisture, pH and compaction), and ineffective control of environmental conditions, more-so than stocking density; high ventilation rates, and the maintenance of appropriate air temperature and relative humidity, appear to be the most important factors in maintaining good litter (see B3.4a). Since the cause and pathogenesis are likely to be similar it is, therefore, unsurprising that FPD is also observed in broiler breeders, even although these birds are stocked at much lower density than broilers; however, the prevalence and severity of FPD within breeder flocks remains relatively unstudied. Kaukonen et al. (2016) observed foot pad condition to deteriorate towards slaughter age in breeder hens, at which point the majority (64%) of birds had severe FPD lesions (scored 4 on a 5-point severity scale). FPD score was positively associated with litter moisture, pH, and percentage slatted area; interestingly, litter condition in breeder houses did not appear to fully explain foot pad deterioration, since the maintenance of dry, friable litter over the whole production period did not guarantee foot health (Kaukonen et al., 2016). Unlike broilers, the feet of breeders make contact with plastic slats in addition to litter, and the elevated slats are often used for roosting; bird mass, time spent on the slatted areas, and slat design may all be important factors in determining FPD prevalence and severity in broiler breeders. Renema et al. (2007) report that breeder hens with severe FPD lesions (scored using a 3-point system) suffered compromised health, including poor body condition (less abdominal fat) and reduced fertility (28% of birds with severe lesions were classified as out of lay, compared with 15% for hens with no lesions). It is strongly believed that severe lesions can cause pain, whether infected or not, which constitutes a welfare issue; furthermore, lesions can be a gateway for secondary bacterial infections which can lead to joint inflammation (see B3.4d). A 5-point scoring system for FPD already provides a useful welfare indicator in broilers (Welfare Quality®, 2009), and this system could also be routinely used to assess FPD in breeders. Contact dermatitis has been shown to have a moderate degree of genetic heritability and a low genetic correlation with body weight; this means that it should be possible to select against susceptibility to FPD without compromising production traits (see B3.4a).

BB3.8b Hockburn

The hock is the ankle joint of the chicken, and hock burn (HB) is a form of contact dermatitis affecting the skin of the caudal (back) part of the hock joint. As with FPD, the prevalence and severity of HB within breeder flocks remains unstudied. Kaukonen et al. (2016) report the prevalence of hock lesions in Finland as 'rare'. This is unsurprising as HB is associated with leg weakness in commercial broilers (i.e. high levels of inactive behaviour, sat with hocks in contact with poor quality litter), and breeders have a fairly low incidence of leg problems.

BB3.8c Toe pecking

Sandilands et al. (2006) observed toe-pecking in an experimental pen of birds fed a qualitatively restricted diet. This has obvious consequences for foot health and has also been reported in laying hens (see LH3.8).

BB3.9 Parasitic infections

Parasitic infections are predicted to have a low impact upon broiler breeder welfare due to low prevalence as a result of high biosecurity measures.

Very little data is available regarding any parasitic infection in broiler breeders. Due to the production companies needing to maintain a high health status for economic reasons it would be anticipated that parasitic infections are pro-actively managed against, occur rarely, and are rapidly treated when they do arise.

BB3.9a Mites

Red mite (*Dermanyssus gallinae*) and Northern fowl mite (*Ornithonyssus sylviarum*) are known to cause significant welfare problems for laying hens (see LH3.11a) and since control of either is difficult, even using synthetic acaricides, it is likely that at least some free-range broiler breeder flocks will be negatively affected by these ectoparasites. If left untreated, mite infestations of either species will cause birds to become anaemic and less productive. Kaoud and El-Dahshan (2010) report that red mite infestations cause immunosuppression in broiler breeders and have deleterious impacts upon performance (reducing egg production, and increasing mortality); the authors also hypothesise that a red mite infestation may also decrease the transfer of maternal immunity to any offspring.

BB3.9b Coccidiosis

Coccidiosis is a common parasitic disease of broiler breeders caused by single-celled protozoan parasites of the genus *Eimeria*. Although *Eimeria* has developed drug resistance against most anticoccidials in use today, several effective vaccines have now been developed, including some whereby vaccination of breeder hens leads to the protection of broiler offspring (Sharman et al., 2010). Further research to develop fully effective vaccines continues (see LH3.11b).

BB3.9c Worms

Broiler breeders housed within a system with outside access are at risk of acquiring a variety of parasitic worm infections since they will have contact with the droppings of wild birds; the consequences of infection are similar to those seen in laying hens (see LH3.11c), including suppressed productivity and compromised welfare.

BB3.10 Infectious disease

As a consequence of high biosecurity measures and comprehensive treatment regimes infectious disease has less of an impact upon breeder welfare than is seen in broilers; E. coli remains a main cause of poor health.

Since the majority of cage and non-cage systems have very high standards of biosecurity, infectious disease is, generally, not a major cause of mortality in broiler breeders or grandparent lines. An exception is *E. coli* peritonitis syndrome (EPS) which causes more acute and serious infection and mortality than the more commonly described salpingoperitonitis or 'egg peritonitis', and is a condition to which broiler breeders appear particularly susceptible regardless of housing system (Landman and van Eck, 2015). Broiler breeder flocks in the Netherlands had a farm-level incidence of EPS of 35%, much higher than the incidence seen in flocks of layer breeders (7%), free-range laying hens (12%) or caged laying hens (1%); the severe welfare and economic impact of this condition suggests a need for further research (Landman and van Eck, 2015). Other infectious diseases that may cause ill health in broiler breeders include: (a) navel/yolk sac infections caused by *E. coli*, (b) systemic infections with *Staphylococcus aureus* and *S. tendovaginitis* (affecting 10-30% of flocks) and (c) *Erysipelothrix rhusiopathiae* (affecting less than 1% of flocks) (AHAW, 2010). Treatment with antibiotics is effective for some but not all of these conditions, and is expensive (Landman and van Eck, 2015). An outbreak of infectious bursal disease in a broiler breeder flock in Iran was reported to increase the male mortality rate, compared to a non-infected flock, at 12 weeks (Salahi et al., 2014).

BB3.11 Immune function

Broiler breeder immunity becomes suppressed following chronic stress and/or mite infection, and may be compromised following exposure to outdoor ranges, high ammonia, high temperatures and fungal feed contamination; lowered immunity increases the risk of secondary infections and poor welfare.

There is very little data relating aspects of husbandry to broiler breeder immunity; however, since exposure to chronic stress is often seen to suppress immunity (Shini et al., 2010) we can assume that severe dietary restrictions and exposure to prolonged aggression must take their toll. We know that red mite infestations suppress immunity in breeders (see BB3.9a), and peritonitis is linked to immunosuppression following the rapid rise in plasma oestrogen at the onset of lay (Hocking and Bernard, 2000). Evidence gleaned from broiler studies can help us infer that organic free-range broiler breeder flocks will be subjected to greater immunological challenges than the high-biosecurity flocks housed indoors, and that exposure to high levels of ammonia, high temperatures, and mycotoxins (food contamination) will suppress broiler breeder immune systems (see B9.2, B9.4 and B2.4). In addition, broilers that were incubated in the dark have been seen to demonstrate greater immunosuppression following crating (as grown birds) than broilers incubated under light, and

regular human (visual) contact between 1-21 days of age was sufficient to maintain a higher antibody response in broilers following handling and crating, compared to broilers that had never had human visual contact (see B7.2).

BB4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

The majority of studies that have documented behaviour in broiler breeders have focused upon stereotypic pecking associated with feed restriction, have observed birds in housing without enrichment and, subsequently, have analysed behaviour using relatively basic ethograms, e.g. walk, stand, rest, eat, drink, preen, peck feeder, peck litter, peck drinker, peck flock-mate (de Jong et al., 2002; Merlet et al., 2005; Puterflam et al., 2006; Hocking et al., 2007). Apart from identifying an obvious requirement for more food, these studies provide very little information regarding the behavioural needs of breeders. Hocking et al. (1993) demonstrated that the time spent on different behaviours was similar for restricted fed broiler breeders and laying hens. In the absence of data for broiler breeders we may assume that their motivation to perch, forage, dust-bathe and perform social and comfort behaviours is similar for that reported for laying hens (see LH4).

BB4.1 Behavioural need for a nest

Broiler breeders appear to be motivated to nest within nest-boxes so a sufficient number of an appropriate design should be provided.

Very few studies have been conducted on nesting behaviour in broiler breeders. Laying hens demonstrate a strong innate motivation to nest (see LH4.1), and it is safe to assume that breeders share the same drive to lay their eggs within a suitable nest site with minimum stress for the sitting hen (i.e. away from flock-mate disturbances). Breeder hens certainly use nest-boxes when provided, although they tend to lay more floor eggs than laying hens; in a study by Holcman et al. (2007) 5.1% of all eggs were laid on the floor, but this percentage was seen to decrease over time. In this study some subordinate hens were excluded from certain nests, so the number of floor eggs may have been lower if these subordinates had had access to their preferred nest sites at the time of oviposition. Further evidence for breeders to demonstrate motivation to lay within nest-boxes is provided by Sheppard and Duncan (2011). They hypothesised that feeding birds during the morning nesting period was causing the hungry hens to lay their eggs on the floor; however, although the hens did leave their nests to eat, the vast majority returned after the meal and proceeded to lay in the nest-boxes (Sheppard and Duncan, 2011).

BB4.2 Behavioural need to perch

Perching (and roosting) motivation in broiler breeders is likely to be similar to that of laying hens, and much greater than that demonstrated by broilers due to the restricted mass imposed by feed restriction.

Although perches are an obvious environmental enrichment for broiler breeders, raised slatted areas and/or platforms are often used as an alternative in broiler breeder houses. Breeders have a requirement for a comfortable secure physical environment that allows undisturbed rest, and facilitates the avoidance of undue aggression. Perches and platforms would make a positive contribution towards providing this but there is scarce data regarding the design or use of perches and platforms for breeders. The provision of breeder pullets with perches during rearing has been seen to attenuate fear, as measured by tonic immobility (Brake et al., 1994). Since laying hens demonstrate a high motivation to reach an elevated area, at least, at night (see LH4.2a) it may be assumed that breeders have a similar 'need' to roost and, as such, sufficient perch/platform space should be provided.

As for layers, broiler breeders should be provided with perches from an early age to meet the behavioural needs of the birds, to assist in the development of mobility and spatio-cognitive skills (ability to navigate through a three-dimensional environment), to assist in accessing resources, and to maximise the potential use of elevated structures during the production period (i.e. perches, platforms and raised nest-boxes). The opportunity to learn perching behaviour during rearing appears to influence laying and nesting behaviour in broiler breeders. Brake (1987) observed that breeder hens reared in the presence of perches exhibited a significantly reduced incidence of floor-laid eggs compared with hens reared without perches. Providing broilers with elevated enrichment, including straw bales and perches, has been shown to encourage increased physical activity, stimulate a greater variety of motor patterns, and improve leg health (see B5.6). Although broiler breeders are more active and likely to perch than broilers perch provision during rear may also benefit their leg strength. Breeders housed with wood-shaving bales during rear went on to maintain better eggshell quality with age compared to birds housed without enrichment, although there was no difference in egg production; the authors hypothesise that early access to perches may have improved bone quality, which in turn may have increased the Ca source available for sustained eggshell production (Edmond et al., 2005). European legislation concerning minimum standards for the protection of laying hens states that adequate perches should be provided in enriched cages as well as in alternative systems for laying hens (AHAW, 2010), and there is every reason that similar recommendations should also apply to broiler breeders.

BB4.3 Behavioural need to forage

Since broiler breeders demonstrate an innate drive to perform foraging (litter-pecking) activity a suitable substrate (good quality litter) should be made available.

Broiler breeders, like layers, spend a large proportion of their day performing active foraging behaviour (litter pecking and ground scratching). This is highlighted by a study which compared time-budgets of standard and dwarf breeders fed *ad libitum* and standard breeders subjected to quantitative feed restriction; 10-12% of all behaviour performed was foraging (litter-pecking), regardless of diet and, presumably, hunger (see Figure BB1: Puterflam et al., 2006).

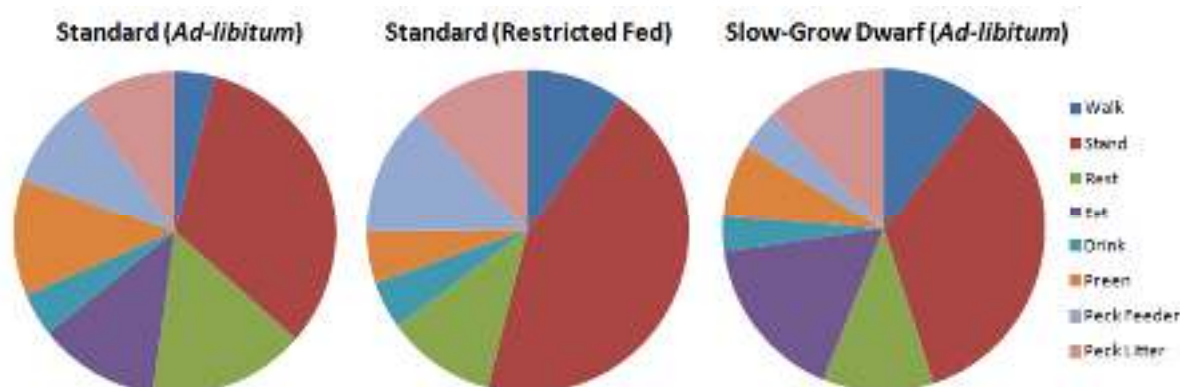


Figure BB1: Time-budget (%) during the rearing phase of *ad libitum* fed standard breeders, restricted-fed standard breeders and *ad libitum* fed dwarf breeders, 1 hour prior to feeding (data from Puterflam et al., 2006)

Hocking et al. (1996) observed that breeders restricted to different proportions of *ad libitum* body weight spent similar proportions of time in total pecking activity. Breeders housed completely on slats were observed to spend proportionally more time standing, pecking the pen walls and other birds, and less time foraging and litter pecking than with birds housed completely on litter (Hocking et al., 2005). These results suggest that broiler breeders have an in-built drive for foraging activity that might be directed at inappropriate targets if suitable litter, or space for foraging, is not available. In addition, feed-restricted broiler breeders will work for the chance to perform exploratory and foraging behaviour (the appetitive phase of feeding) in the absence of a food reward (Dixon et al., 2014). The high level of foraging motivation, even in the absence of food, is consistent with the suggestion that foraging behaviour in feed-restricted birds has de-arousing (stress reducing) properties (Savory et al., 1992), and this provides additional evidence for the fundamental need for the provision of a suitable substrate (i.e. good quality, dry friable litter) in which breeders are able to perform this activity.

BB4.4 Social behaviour

Although flock synchrony can be predicted, very little is known regarding social behaviour in broiler breeders. The provision of artificial cover could help alleviate aggressive interactions.

Very little data is available regarding social behaviour in broiler breeders, other than the tendency for breeders to perform incomplete courtship behaviour, and the associations of this with aggressive mating (see BB3.6). Marin et al. (2001) provided evidence for broilers to distinguish between familiar and unfamiliar individuals in novel environments; however, studies on laying hens suggest that once the group size exceeds around 100 individuals, laying hens cannot distinguish between familiar and unfamiliar birds (see LH4.5). In both small and large flocks of chickens synchrony in the performance of behaviours such as feeding, dust-bathing and resting is commonly observed, and this is also likely to occur within breeder flocks, especially at meal-time. Facilities must, therefore, account for the tendencies of breeders to cluster; for example, the length of feed troughs should be sufficient to enable all birds to feed at once. Not only could the provision of vertical mesh panels within the central litter area provide a means for females to escape unwanted attention from males, as seen in the study of Leone and Estevez (2008), but such cover could also offer subordinate males a means of avoiding aggressive male-male interactions.

BB5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

No comprehensive data are available regarding husbandry and management systems of broiler breeders and little research has been conducted to study broiler breeder behaviour in any specific system. The health of the broiler breeders has the potential to affect the health of large numbers of commercial broilers so, to provide healthy chicks for production, it is considered crucial to manage their environment to be as disease-free as possible. Biosecurity, hygiene, and disease control are essential criteria in the design of breeder houses and their management. Grandparent stock are usually housed and managed in a similar manner to broiler breeders, but at lower stocking rates and with even greater biosecurity.

BB5.1 Conventional cages

Conventional cages are not appropriate for housing broiler breeders as they do not fulfil the behavioural needs of the birds.

In broiler breeding programs, a lot of selection criteria have to be measured individually and some of them can only be measured in specific environments such as individual cages or challenging conditions (e.g. robustness in a poor environment); as a consequence, some grandparent lines are housed in conventional group cages (without any enrichment) and artificial insemination is used for breeding (de Jong and Guémené, 2011). A small proportion of breeder hens (equivalent to 1-2% of all European breeding stock) are also single or group housed in conventional cage systems (AHAW, 2010). There is no literature on the effect of cage housing on broiler breeder welfare; however, since restricted-fed breeders and laying hens demonstrate similar behaviour (Hocking et al., 1993), we can assume that the effect of barren conventional cage housing on breeder welfare will not differ significantly from that of layers. Since laying hen studies have demonstrated that barren cages (without perches, litter and nest boxes) do not fulfil the behavioural needs of the hens (see LH5.1), this system is also unlikely to fulfil the behavioural needs of broiler breeders, and will, thus, severely compromise their welfare.

BB5.2 Furnished (enriched, colony) cages

Furnished cages for use with broiler breeders should be of the same standard currently used to house laying hens, i.e. contain litter to facilitate foraging and dust-bathing behaviour.

A limited number of farms house broiler breeders within multi-tier ('colony') cage systems during the production period. Each cage houses about 60-100 birds, allows natural mating, and is furnished with nests and perches, but without litter; less than 5% of European parent stock are housed within such systems (AHAW, 2010). Behaviour within this cage-type may be hypothesised to be similar to that observed in layers maintained within enriched cages (see LH5.2); however, since breeder cages do not have litter they are not completely comparable. Dust-bathing and foraging behaviours are known to be important for chickens in general, and are also likely to be highly-motivated behaviours for broiler breeders (see BB4.3). Space restrictions within the cages and the inability to fully perform motivated behaviours within this housing system will have a negative impact upon the welfare of these birds.

BB5.3 Non-cage systems

The provision of females with elevated structures from a young age increases mobility and promotes access to the nest-boxes later on; modern nest-box design is optimum for egg collection but not ideal for the birds themselves. Good quality dry litter is essential for maximising constructive, and minimising aversive, behaviour; however, behaviour within these systems remains largely unstudied.

Two types of standard non-cage indoor housing system operate for broiler breeders; birds are either reared and lay within a single facility or, as per the American system, birds are transferred from rearing quarters to a production unit (laying house) with greater feeder space.

BB5.3a Housing during the rearing period

Standard breeder rearing houses are usually window-less as light exposure (photoperiod) is strictly managed to control sexual maturation; however, in Sweden it is a legal requirement to provide windows. During rearing litter (usually wood-shavings, peat or straw) usually covers the entire floor area. Perches or raised platforms are sometimes provided for the female groups at rear, to accustom the hens to different levels, and enable them to acquire balance and improve their mobility (develop jumping skills, etc.) to facilitate nesting behaviour later (Estevez, 2009, cited by AHAW, 2010). Pelleted feed may be scattered on the floor manually, or via 'spin feeders', to encourage foraging behaviour, decrease food competition, and improve uniformity of body weight (Hocking et al., 2004); grain, grit or oyster shell may be distributed in a similar manner as additional enrichment.

BB5.3b Housing during the production period

Usually, houses have a littered scratch area (50-80%) and a raised slatted area (20-50%) positioned at a height of ≤ 60 cm above the litter surface. Non-cage systems provide space and resources for the birds to perform a wide range of active behaviours, including locomotor and comfort behaviours, nesting, dust-bathing and foraging. Enrichment is not commonly used in production houses, although sometimes perches and elevated platforms (required by legislation in Sweden and Norway) are present. There are no data on the use of these elevated structures (proportion of birds using them, or whether they are predominantly used at night or day). Maintaining good quality dry litter (often wood shavings or straw) is essential for keeping the nests and eggs clean and preventing FPD (see BB3.8). However, with insufficient ventilation litter areas can become wet and compacted (see BB8.3). Hocking et al. (2005) observed less floor pecking and higher injurious feather pecking in breeders housed on just slats; this highlights the need to maintain good litter conditions to facilitate natural foraging in feed-restricted birds and minimise adverse behaviour.

Natural mating is used in non-cage systems and aggression by males to females during mating can cause severe welfare problems (see BB3.6); however, the range and prevalence of typical injury severity within commercial production systems remains unknown. Nest-boxes are positioned on the slats and can either be individual boxes containing litter (wood-shavings or straw) with manual egg collection or, more commonly, collective nests with an automated collection belt. The industry in Europe recommends 4-5 hens per individual nest-box, or 40-90 hens/m for automatic collective nests (AHAW, 2010). If some hens do not use the nest boxes then the resultant floor eggs are difficult to collect and likely to be dirty or broken (causing economic loss). Hens may lay outside the nest-box due to competition for a preferred nest-site or a sub-optimal nest-box design. The majority of automated collection nest-boxes in use contain astro-turf or rubber matting (to minimise egg contact with the nest-box floor) and have an angled floor that allows the egg to roll onto a conveyor belt at the back of the nest-box. However, breeder hens appear to 'prefer' metal nest-boxes containing litter (63% of all eggs laid); less than half this number of eggs were laid in larger wooden nests with litter (30%), and only a very small number were laid in metal nest-boxes with rubber matting (2%) (Holcman et al., 2007).

BB5.4 Free-range systems

Access to outdoor space will provide broiler breeders with the potential to perform a wide range of behaviours, but will carry a greater risk of exposure to infections and disease than indoor systems.

A very small number of organic broiler breeders are reared in free-range systems, but there is no specific data relating to their associated health and welfare issues. Although these birds have access to outdoor space and are able to demonstrate a full repertoire of natural behaviours, they may be at an increased risk of contracting infections and disease (see LH3.11b; LH3.12; B6.2), and will be exposed to ambient temperature and photoperiod. It has been suggested that the outdoor ranges of broiler flocks could be planted with nutritious forage as well as larger bushes and trees (see B6.1), and this is something that may benefit feed-restricted breeders and encourage them to forage outdoors and make full use of the outdoor space.

BB6. FEAR AND DISTRESS

BB6.1 Stress

The use of markers of physiological stress to denote psychological stress in feed-restricted broiler breeders is confounded by the influence of metabolic stress. Chronic male aggression is likely to be a key stressor in non-cage housed systems.

Incubation conditions influence the post-hatch stress response of broilers; the provision of light during incubation reduces corticosterone levels in chicks following handling, and in grown broilers following crating, compared to broilers incubated in darkness (see B7.2); this is also likely to apply to breeders.

Plasma corticosterone is elevated in feed-restricted broiler breeders during rear compared to birds fed *ad libitum* and there is a positive relationship between the level of feed restriction and corticosterone (see BB2.1c). Although these results may indicate that restricted breeders are chronically psychologically stressed (i.e. are experiencing feelings of hunger or frustration) they are also likely to be subject to metabolic stress since corticosterone has a key role in energy homeostasis and the regulation of blood glucose levels. However, feed restricted birds also demonstrate an elevated corticosterone response to an acute stressor (i.e. they are more responsive to stress; see BB2.1c). The use of white blood cells as an index of chronic stress associated with food restriction has come under question, as although H:L ratios do increase following feed restriction, extreme differences in body weight appear necessary (see BB2.1c). During rearing, feed may be provided every day or via skip-a-day feeding programmes; however, neither behavioural measurements, nor H:L ratios, have demonstrated differences in stress indices between these two feeding regimes (Skinner-Noble and Teeter, 2009). Scatter-feeding and feeding twice daily during rearing increased eating time but had no positive effect upon physiological measures of stress and hunger (de Jong et al., 2005b). Research in this area remains very limited and more studies will be necessary to draw firm conclusions about feeding programmes in relation to bird welfare.

Stocking rate (5-11 breeders/m²) was not seen to influence H:L ratio (Spinu et al., 2003). Housing feed-restricted broiler breeders under low or high ambient temperatures (annual range: 7-33 °C) did not appear to affect H:L ratios either; however, increased basophil numbers were observed at low temperatures (Spinu et al., 2003); unlike the H:L ratio, which is often seen to return to baseline over time, basophil levels tend to remain elevated, and can thus be indicative of prolonged stress (Maxwell et al., 1990, cited by Spinu et al., 2003). Breeders housed on litter for 0-4 weeks and then moved onto a slatted area without litter had higher corticosterone concentrations than groups continuously housed on either litter or slats, or slats then litter; this suggests that the birds found the removal of this resource stressful (Hocking et al., 2005).

Male aggression is a prime cause for high stress levels in breeder flocks as both males and females can be subjected to harassment and sustain injuries (sexual and non-sexual) (see BB2.1b, BB3.5 and BB3.6); environmental enrichment, such as vertical mesh-covered panels, could be used to reduce stress and fearfulness and improve bird welfare (Leone and Estevez, 2008). Cage-housed breeders are likely to suffer from distress due to the restraint and handling associated with artificial insemination procedures (AHAW, 2010).

Regular, positive, stockman contact appears to be useful in reducing stress reactivity in broilers; regular human (visual) contact within the first 3 weeks reduced stress reactions (H:L ratio) to handling and crating, compared to broilers that had never had human visual contact. Subjecting broilers to 'pleasant' human contact (gentle stroking) has also been reported to reduce stress reactions (H:L ratio and corticosterone) to transportation compared to a control treatment (no contact); broilers subjected to unpleasant handling (inverted swinging and aversive noise) had similar stress responses to the control group (see B7.4).

BB6.2 Fear

Fearfulness triggered by male aggression may be alleviated via the provision of enrichment (especially elevated structures); as observed with broilers, the provision of light during incubation could also produce less fearful and stress-responsive breeder chicks.

Parental effects and incubation conditions have been shown to be important in influencing the fear response in broilers, and these factors may also apply to broiler breeders themselves. Broilers produced by young breeders are more fearful than broilers produced by older breeders (see B7.2). Since broilers exposed to light during incubation were also shown to be less fearful than birds incubated in darkness, this suggests that light stimulation during embryogenesis produces chicks that are better adapted to the hatchery environment (indicated by long-term reductions in fearfulness and stress) and, as such, have improved post-hatch welfare (see B7.3); this is also likely to apply to breeders.

Regular, positive, stockman contact appears to be useful in allaying fear in broilers. Even brief physical restraint can elevate underlying fear levels in broilers, and this effect can persist for at least one hour after the event; however, regular human (visual) contact during the first 3 weeks reduced fear to handling and crating, compared to broilers that had never received human contact. Subjecting broilers to 'pleasant' human contact (gentle stroking) has also been reported to reduce fear reactions to transportation compared to a control treatment (no contact); broilers subjected to unpleasant handling (inverted swinging and aversive noise) had similar fear responses to the control group. Correlations between negative stockman attitudes, broiler fear of humans and mortality have also been identified (see B7.4).

Aggression by male birds (sexual and non-sexual) is common during the production period (see BB2.1b and BB3.6). Millman et al. (2000) observed broiler breeder hens to demonstrate behaviour associated with fear (including huddling, standing alert and alarm calling) in pens where males displayed high levels of aggression. Broiler breeder pullets display an increase in fear responses (as assessed by tonic immobility) with age; however, the provision of enrichment (perches) during rearing has been seen to attenuate this increase in fear (Brake et al., 1994).

BB6.3 Impact upon production

Fear and stress are linked with reduced reproduction and production parameters (including eggshell quality and hatchability). The provision of enrichment (especially panels to provide 'cover') has been reported as helpful in reducing female fearfulness and stress.

Jones (1996) suggested that both eggshell quality and hatchability are reduced in fearful birds. Thus, it could be hypothesised that, birds reared within an enriched environment will be less aggressive, and hence less fearful, within the production period (lay) and will, as a consequence, produce better quality eggs. The provision of vertical mesh-covered panels to provide artificial cover within the litter area of breeder sheds was seen to improve the flock reproductive performance, for reasons presumed to include reduced levels of female stress (Leone and Estevez, 2008).

BB7. SENSORY ENVIRONMENT

BB7.1 Light and vision

Photostimulatory lighting regimes need to be carefully synchronised to prevent undesirable male sexual activity before the females are receptive; courtship behaviour is not improved, nor forced matings reduced following the provision of UV_A light. A photoperiod of 16L:8D and light intensity of 600 lux appears to be appropriate during the production period (lay).

The majority of research concerning broiler breeders and lighting has focused upon photoperiod, sexual development, and egg production. Lighting programmes for breeders are very similar to those recommended for laying hens, yet very different from those recommended for broilers. These usually comprise an 8 hour photoperiod during rear, then a transfer to a mildly stimulatory day length of 11-12 h at approximately 20 weeks, followed by a series of weekly increases in day-length to reach 15-16 h by 28 weeks (AHAW, 2010). From a welfare perspective the timing of sexual maturation in males and females is important and should be synchronised (i.e. males should not be exposed to longer photostimulatory lighting regimes before 20 weeks) to prevent undesirable sexual activity before the females are receptive (see BB3.6).

Lewis (2006) suggests that 12 h days during production are perfectly adequate for optimising egg production and shell quality, and the step-up lighting regime is not necessary; day-length does not appear to influence the prevalence of floor laid eggs. Broiler breeders respond to light, in particular photoperiod, differently from modern laying breeds because they still exhibit photorefractoriness (a natural phenomenon that prevents animals becoming sexually active when subsequent environmental conditions are likely to be sub-optimal for rearing offspring) (Lewis, 2006). Typical broiler breeding companies recommend a bright light intensity of around 20-100 lux for the first 2 days in the brooding area, which is then gradually reduced to 10-20 lux between 7-21 days (and maintained until around 20 weeks), and then increased to 40-60 lux for the duration of the laying period (AHAW, 2010). Light intensities of 20-40 lux may be used for non-beak-trimmed birds, to prevent injurious pecking. Lewis et al. (2009) verified that these recommendations were appropriate for non-cage systems; they determined biological optima for egg production as 15 lux during rear and 7 lux in the laying period; hens illuminated at 25 lux in the laying period laid more floor eggs than at either 55 or 70 lux.

It is known that layer hens have a well-developed colour vision and have the ability to see in the ultraviolet (UV) range (see LH7.1). Jones et al. (2001) hypothesised that the absence of UV_A light (320< λ <400 nm) provision to commercially reared sexually-mature broiler breeders may potentially explain why forced and aggressive matings are commonplace; if sub-optimal light sources hinder effective social signalling, then this could alter behavioural patterns and reduce mating cues. Breeders generally exhibit limited courtship displays (see BB3.6). Under experimental conditions birds were seen to demonstrate a consistent preference for 14-6% UV_A, corresponding with natural sunlight (and the light environment to which the birds are genetically adapted); however, although a UV_A-enriched environment improved sexual selection and increased mating frequency, courtship behaviour was still infrequent and the majority of matings remained forced (Jones et al., 2001).

There is no literature specifically documenting the relationship between light intensity and feather pecking in broiler breeders, although Hocking et al. (2004) report an incidence of injurious pecking and cannibalism in experimental flocks from 4 weeks of age, which was presumed to be caused by conditions of relatively high and variable light intensity. Laying hens are often maintained at low light intensities commercially to reduce the risk of feather pecking; however, low light intensities (< 10 lux) have been shown to have negative effects upon broiler eye health (see B8.1b). At very low light intensities (≤ 1 lux) laying hens' mobility is impaired, they are no longer able to jump between horizontal perches and move freely around the house; in addition, social evaluations and communication may also be disrupted (see LH7.1). Because laying hens and broiler breeders are fundamentally biologically similar, it can be assumed that very low light intensity will also affect these behaviours in broiler breeders.

BB7.2 Thermal comfort

It is important to maintain broiler breeders within the thermoneutral zone since dietary restrictions leave them less able to meet raised metabolic requirements associated with extreme temperatures; deviations in air temperature may lower welfare further by inducing further hunger and stress, and potentially triggering further aggression as a consequence.

The rearing house temperature is adjusted to approximately 30 °C on the first day of placement, and is then gradually decreased to 18-22 °C. For economic reasons the majority of broiler breeders will be housed within the temperature range required to keep them comfortably warm, the thermoneutral zone (20-25 °C), as temperatures below and above this range are likely to impact upon egg production, especially when dietary restrictions leave them less able to meet raised metabolic requirements associated with extreme temperatures. The small number of breeders housed within free-range systems with outside access will encounter variations in temperature and humidity, which is a disadvantage of these systems for breeders. Evidence for increased hunger, frustration and stress following exposure to low ambient temperatures has been provided. Spinu et al. (2003) observed an increase in stereotypic object pecking, ground pecking, walking, preening and drinking during the cold season in breeder hens housed at ambient temperature (annual range: 7-33 °C), while during the hot season more time was spent lying (presumably to minimise heat production) and feeding (i.e.

they consumed their feed ration slower than under cold ambient temperatures). Higher basophil numbers under low air temperatures indicated prolonged physiological stress (Spinu et al., 2003). Pereira et al. (2007) observed breeders housed in small groups to demonstrate more chasing, feather pecking and foraging (ground-pecking and litter-scratching) at low ambient temperatures (13 °C); this is likely to reflect feeding competition as energy requirements increase at temperatures below the thermoneutral zone. During warmer ambient temperatures (35 °C) breeders, again, decreased their locomotory activities and spent more time resting (Pereira et al., 2007).

BB8. HANDLING AND MANAGEMENT

BB8.1 Stocking density and group size

A reduction in stocking density may reduce feather damage and have positive effects on sexual behaviour and broiler hen performance.

Stocking rate may vary considerably between farms and countries. In most countries the stocking rate of broiler breeder flocks during the rearing period is not limited by legislation. Stocking rate in EU countries generally ranges between 5-8.5 breeders/m² (approximately 20-34 kg/m² at 60 weeks), while grandparent stock are housed at lower stocking rates during both the rearing (6 males/m² and 8 females/m²) and production (6.5 birds/m²) period (AHAW, 2010). The percentage of males placed in the production house at the age of transfer varies between 8-11%, with the aim to have a maximum of 7-9.5% males at 23 weeks of age when egg production starts and 6% at 60 weeks of age (AHAW, 2010).

There are few data available on the effect of stocking rate on broiler breeder welfare. Reducing the stocking rate of broiler breeders during the rearing phase (standard: 14.5 hens or 8.0 males/m²; low: 7.25 hens or 5.5 males/m²) was seen to alter behaviour; females performed more foraging and males performed more walking at the lower stocking rate; feather and skin damage was comparatively less in both males and females at the low stocking rate (de Jong et al., 2011). Lowering stocking rate of breeders during the production phase improved their production performance as well as their feather condition (de Jong et al., 2011). Reducing the stocking rate during production (standard: 8.0 birds/m²; low: 4.75 birds/m², 10% males) led to more courtship behaviour and a higher proportion of completed matings, as well as fewer forced matings and less hen struggling; less feather damage in the hens at the low stocking rate was probably due to more appropriate mating behaviour (de Jong et al., 2011). Spinu et al. (2003) observed stereotypic object pecking to increase with increased stocking rate (5 vs 11 birds/m²).

BB8.2 Air quality and biosecurity

High levels of ammonia and dust (including disease-causing organisms) can have adverse effects upon broiler breeder health, but can be controlled via the use of adequate ventilation and air purification systems. A maximum ammonia concentration of 20 ppm is recommended to maintain bird health and comfort.

The air quality in broiler breeder houses is dependent upon many factors including air temperature, relative humidity, ammonia, dust, micro-organisms, stocking rate, ventilation rate, litter type and quality, and bird age. The main sources of aerial pollutants are the feed, the litter and the birds themselves. During the course of lay broiler breeders are usually housed on a combination of litter (scratch area) and slats; as with layer houses a deep pit under the slatted floor area collects manure until the house is cleaned at the end of the production period. Modern broiler breeder houses generally utilise negative pressure ventilation, whereby exhaust fans pull air out of the house, which creates a partial vacuum inside the house, and this then draws in fresh air through air inlets. Many older laying houses operate mainly via natural ventilation, opening curtains and employing tunnel ventilation during hotter weather.

The majority of airborne particles in poultry houses are organic in origin, with bedding, faeces, skin, feathers, feed and micro-organisms contributing to the inhalable and respirable particles (Banhazi et al., 2008). Very dry litter may lead to high dust concentrations which can irritate the respiratory tract of birds; dust in broiler houses can be minimised through the use of proper ventilation, by keeping relative humidity at recommended levels, by performing thorough cleaning between batches of birds, reducing stocking rate, and using low-dust litter materials (see B9.2). Airborne dust is one of the primary means by which disease-causing organisms are spread throughout a poultry house; reducing airborne dust levels by 50% can reduce airborne bacteria by 100 fold or more (Madelin and Wathes, 1989, cited by Mitchell et al., 2004). Airborne transmission of *Salmonella* is a major factor for its spread between birds and contamination of hatching eggs in breeder houses. Interventions, in addition to improved biosecurity, include the use of Filtered-Air Positive-Pressure (FAPP) housing to produce specific pathogen free eggs, or air ionisation systems (e.g. Electrostatic Space Charge, ESC, system) to reduce airborne dust and kill micro-organisms (Mitchell et al., 2004); however, the cost of constructing and operating a FAPP production facility only makes it economically viable for use with valuable grandparent stock. Mitchell et al. (2004) observed airborne dust concentrations within a commercial breeder house, with a slat and litter scratch area, to increase over time during the production period (range: 2 to 6.5 mg/m³); however, use of an ESC system was seen to decrease dust by over 60%. Similarly, airborne bacteria (range: <50-550 CFU/plate under control conditions) were reduced by almost 70% (Mitchell et al., 2004).

Ammonia is produced in the litter or manure pits by microbial decomposition of the birds' faecal waste. Although no recent studies have investigated the adverse health effects of ammonia on broiler breeders, in broilers there is evidence that concentrations above 25 ppm can cause irritation to the respiratory system and the mucous membranes of the eyes, induce corneal lesions, suppress certain aspects of immunity while stimulating pro-inflammation, and suppress food intake and growth rate (see B9.2). Choice tests have been used to demonstrate that broilers 'prefer' to be housed in ammonia concentrations <10 ppm and find concentrations above 20 ppm aversive (see B8.3). Maintaining ammonia levels in broiler breeder houses below 20 ppm appears to be realistic as Mitchell et al. (2004) report concentrations between 5 and 20 ppm in a commercial breeder house with a slat and litter scratch area; these concentrations were reduced by 56% with the use of an ESC system.

BB8.3 Litter quality

Poor litter quality (high moisture, pH and compacted) can negatively impact upon breeder welfare by increasing the risk of foot pad dermatitis and limiting highly motivated behaviours such as dust-bathing and ground-scratching; risk factors include insufficient ventilation (especially during colder months), diet (high protein or high in soluble fibre), and stereotypic drinker manipulation associated with feed-motivated frustration.

Litter (bedding) quality impacts upon broiler breeders' welfare by influencing ammonia levels, dust levels, and relative humidity (see BB8.2 and BB7.4), foot pad skin health (see BB3.8a), and the potential for the birds to perform litter-directed behaviours including dust-bathing and ground-scratching. Litter moisture levels may be affected by a combination of litter material and quantity, drinkers (number and type), water consumption (including water spillage), ambient temperature (i.e. season), stocking rate, ventilation system, bird age, bird health (diarrhoea), and dietary composition. Season has a marked influence upon litter moisture in commercial broiler houses, which is usually higher during colder months due to increases in relative humidity associated with a reduction in ventilation rates, in an attempt to maintain temperature levels (see B9.3).

Hocking et al. (2001) observed that water intake was greater for feed-restricted birds on a control (high protein) diet compared with a low-protein diet and concluded that feeding rations with lower crude protein concentrations may assist in maintaining litter quality. A diet high in insoluble fibre (oat hulls) has been associated with dry friable litter and breeders maintained on this diet demonstrated a low water intake and high levels of dust bathing, while birds provided with a diet high in soluble fibre (sugar beet pulp) had a high water intake, which consequently reduced litter friability and comfort behaviour (Nielsen et al., 2011). Birds provided with a quantitatively restricted standard diet were also observed to use more water than expected and experienced litter degradation (Nielsen et al., 2011); the authors hypothesise that redirected foraging behaviour at the drinker may have been to blame. Jones et al. (2004) also suggest that manipulation of the nipple drinkers may become part of a stereotypic behaviour associated with feed-motivated frustration.

BB8.4 Procedures

The majority of mutilations are carried out on males to prevent them from injuring females during mating, although both sexes are beak trimmed to avoid injurious pecking. All mutilations are associated with restraint, pain and poor welfare, and must, therefore, be performed by highly trained personnel, and be essential in the alleviation of a greater, unavoidable, welfare issue.

In many countries mutilations like beak trimming, de-toeing, and de-spurring are carried out as routine commercial procedures in order to prevent injuries later in life. There is little data on the prevalence of each mutilation, but since all surgical procedures are carried out without any anaesthetic or postoperative analgesia they are all likely to inflict pain and, therefore, have a negative effect on broiler breeder welfare.

BB8.4a Beak trimming

Broiler breeder females are routinely beak trimmed to avoid damage caused by injurious pecking (including feather pecking, aggression, and cannibalism) even though there have only been a few reports of serious injurious pecking documented in experimental studies (Hocking et al., 2005) or commercial breeder flocks (Hocking and Jones, 2006; Morrissey et al., 2014a). Males are beak trimmed mainly to prevent them from injuring females; males tend to peck and grab the back of the female heads during mating (Gentle and McKeegan, 2007; Henderson et al., 2009). Beak trimming needs to be performed within the first 10 days of life to prevent the formation of (chronically) painful neuromas (Cheng, 2006).

When an automated infra-red method is used for beak trimming, this is usually carried out at the hatchery; however, other methods, such as the traditional hot or cold blade, may be performed on the farm (Henderson et al., 2009). No effect on behaviour was observed in broiler breeder chicks that had been beak trimmed by the traditional hot blade method or by an automated infra-red treatment during six weeks following trimming; however, both beak-trimming methods were associated with significant reductions in bodyweight compared to non-trimmed chicks, the hot-blade-trimmed birds being affected the most (Gentle and McKeegan, 2007). In a similar study, Henderson et al. (2009) observed a transient reduction in body weight gain 14 days after beak trim by hot blade compared to chicks either subjected to infra-red beak

trimming or untrimmed (control group). Although physiological measures of stress were not measured as part of these studies, there is a large volume of published research on laying hens to indicate that the procedure is painful and deprives the birds of important sensory feedback from their beaks (see LH8.3b); it can reasonably be assumed that broiler breeders share the same negative welfare implications of beak trimming.

BB8.4b Toe clipping and de-spurring

Toe clipping and de-spurring are carried out on males to prevent the inside claws and spurs from causing feather damage and severe skin lesions to the females during mating; de-spurring also reduces the risk of damage to other males during fighting. Toe clipping may also be utilised for identification of grandparent chicks (AHAW, 2010). Although some of these mutilations may have long-term benefits, the procedure will, at least transiently, compromise bird welfare. Removal of toes (usually the toe that points backwards or inwards) is performed using a hot blade or hot wire, while de-spurring is carried out by thermo-cautery (holding the spurs against a hot metal surface). Even brief physical restraint can elevate underlying fear levels in broilers (Marin et al., 2001), while the mutilation itself will induce acute and/or chronic pain since these tissues are well innervated (Gentle and Hunter, 1988). De-toeing may lead to the formation of small neuromas, the welfare implications of which are difficult to predict (Gentle and Hunter, 1988) although, if associated with chronic discomfort, may impact upon perching behaviour. No studies describe the long-term impact of de-toeing or de-spurring on male chicken welfare. If improvements in housing conditions, management or genetic breeding programmes can alter male breeder mating behaviour then the requirement for mutilations may become redundant.

BB8.4c Comb trimming

Dubbing the comb (cutting off the comb with a pair of scissors) used to be performed on broiler breeder males at the hatchery to reduce the comb size, to prevent damage to the comb (during fighting or from rubbing on the wire roof of conventional cages) and to improve visibility (and thus increase sexual activity). The comb sizes of modern breeder males are much smaller and dubbing is no longer a standard procedure (although it is still performed); it is estimated that <10% of males currently undergo this procedure and only upon customer request (AHAW, 2010). Dubbing is also likely to cause distress from restraint and handling (Marin et al., 2001), and acute pain will result as a consequence of the procedure. There are no studies describing either the acute or long-term effects of comb cutting or the welfare consequences.

BB8.4d Artificial Insemination


Artificial insemination is occasionally used in specific breeding lines to avoid rough mating; however the males have to be individually cage housed, with associated consequences for bird welfare (see B5.1), and the procedure requires a period of restraint, which is likely to cause distress (Marin et al., 2001). In addition, artificial insemination enables the selection of extra-heavy male lines (following the removal of risk for female damage during mating), which poses further consequences for male welfare, especially with regard to the necessity for ever-greater feed restrictions (see BB2.1).

BB8.4e Spiking

'Spiking' is a common management practice in some countries whereby, at around 40 weeks, some of the older males are replaced with younger males, to maintain fertility levels within breeder flocks (AHAW, 2010). 'Double interspiking' involves swapping males between flocks to disrupt the established pecking order and trigger an increase in sexual behaviour. Despite the positive effects on fertility, spiking, unsurprisingly, leads to increased aggression between males and potentially increases the prevalence of forced copulations (see BB3.6), with associated injuries to both males and females. Chung et al. (2012) describe an increase in male-to-male aggression following 'double interspiking'; the authors do not report information relating to male-to-female aggression nor do they report mortality levels prior to, or following, this practice, but there are obvious deleterious welfare implications. In addition, spiking increases the risk of pathogen introduction to the flock and strict biosecurity conditions are therefore necessary.

BB9. WELFARE CONSIDERATIONS: OVERVIEW

When broiler breeders are fed *ad libitum* they become overweight which has negative consequences for their health (including a risk of premature death) and reproductive capacity. To counteract this they are subjected to severe feed restriction (especially during the rearing phase, before the birds become sexually mature). This feed restriction leads to chronic hunger, stereotypic behaviour, aggression and injurious pecking, and has clear negative effects upon broiler breeder welfare. Attempts to increase meal size by diluting the diet with 'fillers' (qualitative restriction) and the use of appetite suppressants do not clearly benefit breeder welfare, nor are these alternative feeding strategies preferred by the birds, since a metabolic 'hunger' remains. A full solution to this paradox is not readily available. Genetics appears to hold the key in addressing many of these issues. The selection of birds requiring less feed restriction as future breeders should be a priority, even if this may involve a compromise in growth rate; the use of different (dwarf) genotypes that require less feed restriction than standard breeders has already been successfully explored.



The majority of mortality in broiler breeders occurs as a result of culling based upon selection criteria; large numbers of males are culled throughout the production (laying) period for poor breeding potential or health issues. Severe foot pad dermatitis has been reported from breeder flocks and steps should be taken (as above) to maintain litter quality.

Sexual aggression is a direct threat to female welfare. Males demonstrate aggression to females in both a sexual and non-sexual context; however, rough mating behaviour, forced copulation and over-mating can leave females wounded and fearful of males. Mating aggressiveness also appears to have genetic origins and could be targeted in breeding programmes. If this could be decreased then the requirement to mutilate would also be lessened. The provision of environmental enrichment may prove beneficial in the short-term. Elevated structures and vertical panels in particular would provide cover and offer a means for subordinate males or females to escape conflict and unwanted sexual attention. The ratio of male to female birds must also be considered.

Males and females are routinely beak trimmed to reduce injurious pecking, while males are often subjected to additional mutilations, such as toe and spur removal, to limit the physical damage inflicted upon other males and females. However, these procedures are conducted in the absence of good quantitative evidence about their potential beneficial effects.

Since so little data exists there is a pressing need for research to establish the prevalence of specific welfare issues, including feather pecking, aggression, skeletal injuries and FPD prevalence in broiler breeder flocks.

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DUCKS

D1. INTRODUCTION

D1.1 Life history

Ducks have been domesticated for thousands of years for their eggs, meat and down feathers. Ducks form part of the family Anatidae, sub-family Anatinae and with the exception of the Muscovy (*Cairina moschata*), all domestic breeds originate from the Northern Mallard (*Anas platyrhynchos*). Despite their common ancestry, independent domestication of the Mallard around the world has resulted in a large amount of phenotypic variation between common domestic breeds. Different breeds are therefore preferred for egg-laying and meat production purposes on duck farms. The Pekin is the most commonly reared breed for meat and can be crossed with the Muscovy to produce the mulard (or mule), which is used for foie gras production in some countries (Ashton and Ashton, 2001). The Indian Runner and Campbell are productive egg-laying breeds.

The Mallard is a Palearctic migratory dabbling species which is found across North America, Europe and Asia, whereas the Muscovy inhabits forested swamps or lakes and is indigenous to central and South America (Appleby et al., 2004). Both ancestral species are largely aquatic and omnivorous, feeding on a broad range of matter including seeds, plants, crustaceans, worms, insects and larvae. They are active and forage most during the early morning and dusk (Ashton and Ashton, 2001). Although their feet are webbed, Muscovies have sharp claws enabling them to roost in trees (Raud and Faure, 1994). This is much less common in the Mallard.

Wild ducks spend a large proportion of their time preening. Preening is essential for maintaining feather condition for insulation, flight and water-proofing and for removing parasites (Ashton and Ashton, 2001). Preening bouts are usually preceded by immersive bathing behaviours (Rodenburg et al., 2005), making open water of great importance for the performance of a full repertoire of behaviours. In the wild, Mallards also undergo a biannual moult to ensure feather condition is maintained.

Whilst the Mallard is a more vocal species using alarm calling as an anti-predator response, Muscovy ducks are a quieter breed. Muscovies can be aggressive, particularly during the breeding season when males use their claws and beaks in agonistic encounters to secure a mate (Rodenburg et al., 2005). In contrast, Mallards use social courtship displays (Miller, 1977) and pair-up in autumn. The pair will remain together (feeding, resting and swimming) for the rest of the breeding season, until a clutch of eggs has been laid. Female Mallards nest on the ground, making a shallow scrape which is lined with insulating material including down feathers (Ashton and Ashton, 2001). Muscovy ducks however, typically nest in tree cavities (Markum and Baldassarre, 1989).

Ducks are closely related to geese, suggesting some of the literature on the welfare of farmed geese is also relevant to ducks. Although chickens are in a different phylogenetic family to ducks, they do share some behavioural similarities, allowing the extrapolation of some information from chickens to ducks. There are some areas in which they differ quite remarkably. Unlike chickens, ducks do not perch (except Muscovy ducks that have sharp claws enabling them to do so) or dust bathe. Instead, they rely on clean water sources for preening and maintaining feather condition.

D2. FEED AND WATER

Food deprivation in early life can slow the development of the small intestine, leading to a reduced body weight. Ducks prefer drinking water from baths over bell drinkers, but only when the water is sufficiently clean. This highlights the importance of providing separate drinking and preening water sources for ducks.

The nutritional requirements of ducks are far less documented than for chickens. In commercial housing, food and water are generally provided *ad libitum*. Early feeding practices and diets can have a profound effect on the development of the digestive system. In some poultry production systems, food and water aren't provided for birds for up to 48 hours, whilst birds are in the hatchery. The impact of delayed access to feed and water for ducklings was investigated in a study which compared food provision 6- and 48- hours post-hatching (Peng et al., 2010). Body weight was adversely affected by 48- hours deprivation and this difference was still observed when birds reached market age at 35 days old. The results suggest that delayed access to food and water initially affected the metabolism and may have caused dehydration, but also slowed the development of the small intestine.

A variety of drinker systems can be used within duck housing systems, ranging from nipple lines to troughs. Unlike other poultry species, ducks not only require water for drinking, but they also have a strong motivation to dabble and use water during preening (Cooper et al., 2002). It can therefore be challenging for producers to supply water sources that satisfy all requirements whilst maintaining sufficient drinking water quality (Liste et al., 2013). Ducks showed a preference for drinking from water baths over bell drinkers when given the choice, but only when the water was sufficiently clean (Liste et

al., 2012b). This suggests that different water sources are required to adequately satisfy all behaviours whilst maintaining hygiene. The provision of water for bathing and preening is discussed in more detail in section D3.6.

D2.1 Force feeding and foie gras production

The production of foie gras involves a period of force-feeding which increases the size of the liver by up to 10-times. The capture and restraint of ducks for force-feeding is stressful.

The production of foie gras (fatty liver) is illegal in many countries worldwide, including Australia, but the product is widely imported. In general, male mulard ducks are reared for this purpose as they yield better quality product than females. Although more productive for foie gras, the mulard is a fearful genotype that can be prone to panic in the presence of humans (Rochlitz and Broom, 2017).

The production of foie gras has been described in detail elsewhere (e.g. SCAHAW, 1998; Guémené and Guy, 2004), but briefly, it involves a period of food restriction during the early growing stage (3-5 weeks from 9 weeks of age), followed by an intense two-week period of force-feeding (from 12 weeks of age) using a pneumatic or hydraulic pump twice daily. Birds are forced to ingest more food than they would do voluntarily. During this process, ducks are fed a high-fat mash which results in an increase in liver weight (up to 10 times the size of a normal liver (Skippon, 2013) and an increased fat content (Rochlitz and Broom, 2017). The procedure causes both discomfort and ill health (Rochlitz and Broom, 2017).

Traditionally, ducks were housed individually in cages during the force-feeding period to ease the procedure for the producer (Guémené and Guy, 2004), but these have more recently been replaced by collective housing systems. Group housing however, involves the capture and restraint of individuals for force-feeding which has been found to be stressful for ducks (Guémené et al., 2006).

There have been some attempts to identify whether force-feeding itself is stressful by examining aspects of duck physiology. In one study, force-feeding caused an increase in serum corticosterone and a decrease in thyroid hormones in Muscovy ducks compared with control values (Mohammed et al., 2014). Other studies however, have observed no significant difference in corticosterone or ACTH before or after force-feeding (Guémené et al., 2001; 2006; Flament et al., 2012). This conflicting evidence is likely to be caused by methodological differences between studies (Rochlitz and Broom, 2017).

The degree of aversiveness of force-feeding ducks was investigated by Faure et al. (2001). Ducks showed some signs of aversion to a test pen in which they had previously been force fed, but not always. Additionally, in the second experiment ducks showed increased flight distances from an unfamiliar person, rather than the force-feeder. The authors concluded that the force-feeding procedure was not aversive, but the experiments have been convincingly described as poorly controlled (Rochlitz and Broom, 2017), and the results could be explained by learned helplessness, a behaviour adopted by an animal when experiencing an aversive situation it has learned it is unable to escape. Rochlitz and Broom (2017) state that ducks initially struggle and resist force feeding, suggesting that it is a strongly aversive practice, but there is a need for further research in this area, drawing on a range of methodologies.

D3. RISK MANAGEMENT

D3.1 Mortality

Higher environmental temperatures in commercial housing systems are associated with higher levels of flock mortality. The age of the parental breeding flock also influences duckling mortality.

In a study on the impact of management system on duck welfare, 46 flocks were monitored in 23 differing housing systems (Jones and Dawkins, 2010a; 2010b). Across all flocks, the average mortality was 5.2% by 48 days (Jones et al., 2010a). High environmental temperatures were associated with higher levels of flock mortality. Temperatures were higher in houses which operated a whole-house brooding system and these conditions were therefore also associated with higher mortality. The type of drinker provided can also affect mortality. In one study, mortality in older ducklings (over 14 days) was higher in houses containing large trough drinkers (approx. dimension: length 183 x width 20 x depth 13cm) rather than a nipple line (Schenk et al., 2016). This may have been due to increased water contamination in the troughs.

Force-feeding during the production of foie gras has also been found to adversely affect mortality. During the two-week period, mortality increased to between 2 – 4%, compared with approximately 0.2% in non-force fed drakes (Skippon, 2013).

An additional factor which is associated with mortality in ducklings is the parent age (Braun et al., 2002). Ducklings from older breeder flocks (31-47 weeks old, rather than 24 weeks old) grew better and mortality was higher in eggs hatched from the younger breeders.

D3.2 Self-directed feather picking, injurious pecking and cannibalism

Ducks can perform self-directed feather-picking which involves the excessive removal of feathers. This can lead to injurious pecking of other birds within the flock. The provision of open water and an outdoor run reduced the amount of feather picking performed and environmental enrichment devices generally improve feather condition.

Ducks can show an auto-mutilation behaviour known as self-directed feather-picking, which involves the excessive removal of feathers during preening. In some cases, this can lead to injurious pecking by conspecifics that are attracted by the altered appearance of pen mates (e.g. a bald patch or a spot of blood), which is also observed in other species of poultry. It has been suggested that feather picking in Muscovy ducks was reduced in housing systems that provided open water sources and outdoor runs and it has been hypothesised that environmental enrichment may reduce the incidences of both self-directed and conspecific feather removal. Colton and Fraley (2014) investigated whether the provision of environmental enrichment devices (coloured plastic balls) in commercial duck housing was associated with improved body and feather condition. They found that at 21 days old, ducks housed with enrichment devices were in better physical condition (feather quality and skin lesions) than those in control groups. Significantly fewer incidences of self-directed feather picking, or conspecific-directed feather pecking were also observed in houses containing environmental enrichment. In the same study, the preferred environmental enrichment colour was also investigated. Significantly more ducks were observed pecking at, or oriented towards the green/blue device compared with red or white devices. The authors suggest the colour preference may relate to the pigmentation of the mallard ancestor and additional work is needed to investigate this further.

Severe injurious pecking can result in cannibalism, which is an issue with farmed Muscovy ducks. Cannibalism can occur early in the rearing cycle and little is known about the reasons for development and preventative measures. To reduce injurious pecking producers may lower housing light levels or trim the bills of birds (see sections D7.1 and D8.2a), but these practices have their own welfare implications. One suggestion is that cannibalism arises when ducks have a strong and unfulfilled motivation for foraging. Riber and Mench (2008) tested this hypothesis, by monitoring the effect of water- and feed- based enrichment on the behaviour of Muscovy ducklings and the development of cannibalism. Overall, enriched ducklings spent more time foraging and less time inactive than control ducklings, but water enriched ducklings used their resources more than the feed-enriched birds. However, regardless of enrichment provision, cannibalism developed in all treatments and began between 15-17 days of age. Additional work is required to investigate the motivation to feather peck and cannibalise.

D3.3 Foot health

Foot condition can be influenced by several factors. Poor quality litter can result in increased foot problems including foot pad dermatitis. Foot pad dermatitis is worse in houses with high relative humidity and ammonia levels. Some drinker types may be associated with increased foot pad dermatitis development, but results are varied. Foot condition was generally good in houses containing open water.

As with other species of poultry, ducks can be susceptible to foot health problems if housed in systems which cause discomfort and injury. The floor substrate used should be appropriate, with sufficient drainage to avoid the build-up of dirt on the foot pads. In a study on the impact of housing and management systems on 46 duck farms in the UK on duck welfare, the quality of straw litter was found to influence the condition of the feet (Jones and Dawkins, 2010a; 2010b). Overall, at slaughter (between 40–56 days old) almost 40% of ducks (from 46 flocks) had raised papillae on the feet and in 13% of cases moderate or severe lesions had formed (foot pad dermatitis - FPD) and 32% of birds had calloused toes (Jones and Dawkins, 2010a). In this study, it was found that high relative humidity and ammonia levels were associated with increased incidences of FPD. The drinker system also influenced the development of FPD, which was worse when ducks were reared in houses with nipple drinkers rather than troughs or bell drinkers. Interestingly, Schenk et al. (2016) found varied results regarding the association between drinker type and the incidence of FPD. At 9 weeks of age, ducks housed with nipple drinkers had significantly worse foot pad scores than those housed with water troughs. By 33 weeks of age the relationship had reversed, with significantly worse foot pads seen in houses with troughs. Although the foot pad condition was comparatively worse, it was not as severe as at 9 weeks in the nipple housed ducks, suggesting that the condition improved with age. An improvement in foot condition during the production cycle was also seen in a study comparing the condition of birds reared on plastic slats and litter (Karcher et al., 2013). Other studies have found that levels of FPD were generally low when birds were housed with open water sources (Jones and Dawkins, 2010a; O'Driscoll and Broom, 2011).

There is evidence to indicate that supplementary dietary biotin, which is a coenzyme involved in the metabolism of amino acids, glucose and fatty acids can lead to a decreased incidence of FPD in ducks (Zhu et al., 2012). Additionally, it has been suggested that reduced egg shell conductivity and increased temperature during incubation is associated with an increased risk of post-hatching FPD development (Da Costa et al., 2015).

D3.4 Leg health

Genetic selection has led to skeletal alterations in ducks. This can influence their walking ability and the prevalence of walking difficulties in commercial duck systems is high. Ducks can also suffer from fatigued walking condition which generally becomes apparent when birds are being transported. Both leg bone and heart development have been suggested to be important in the occurrence of this condition.

Genetic selection of commercial poultry for increased breast muscle mass has resulted in major changes in leg morphology compared with ancestral species (Duggan et al., 2015; 2016). In some breeds, adaptations have led to gait (walking ability) alterations. Unlike other species of poultry, the leg adaptations of ducks need to be appropriate for both swimming and walking, which can make the assessment of appropriate morphology difficult (Duggan et al., 2015). In a study of 46 duck flocks, it was reported that at 23 days old 14% suffered moderate or severe gait abnormalities (Jones and Dawkins, 2010a). By 41 days old, this had increased to 21%. Some work has focused on the impact of altered gait in broiler chickens, some of which is likely to be relevant for ducks, but more work is needed to assess the impact of genetic alterations in gait on the welfare of ducks.

Fatigued walking condition becomes apparent when birds are being loaded into transport for slaughter. Ducks are unable to walk correctly and resort to sitting rather than standing. Little is known about the aetiology of this condition, but it has been suggested that both leg bone and heart development (which can be influenced by egg incubation temperature) both play a role (Da Costa et al., 2016).

D3.5 Infectious disease

Ducks are susceptible to a number of diseases which can cause high mortality including avian influenza, amyloidosis, duck viral enteritis, muscular dystrophy, and goose parvovirus. Higher concentrations of airborne microorganisms in houses can reduce duck immunity, leading to increased susceptibility to disease.

As with other species of poultry, ducks that have access to the outdoors are likely to be more at risk of contracting infectious diseases. Wild ducks are a vector for avian influenza so there is potential for transmission where duck housing allows contact with wild birds. Avian influenza can cause pancreatic and central nervous system damage (Capua and Mutinelli, 2001).

Ducks are particularly susceptible to the development of amyloidosis, which is a pathological chronic hepatic disease. Dinev et al. (2011) conducted pathomorphological investigations on 85 Pekin ducks from a breeder flock between 51-68 weeks of age, to determine the incidence of chronic liver lesions. Microscopic lesions were found in 80% of the livers examined, 56% of which were specifically attributable to amyloidosis. More than half the birds affected also showed signs of ascites, an accumulation of fluid in the abdominal cavity. It is thought that the disease is exacerbated by environmental or physiological stressors (e.g. the onset of lay).

Domestic poultry species can be affected by a metabolic disease known as muscular dystrophy. The disease, which also affects ducks can be caused by amino acid and vitamin deficiencies and can be exacerbated by stress. One study found that subclinical muscle dystrophy altered duck behaviour resulting in increased lying and decreased movement, swimming, bathing and feather cleaning compared to healthy ducks (Bozakova et al., 2012). Environmental stress (high ammonia, ambient air temperature and humidity) further influenced behaviour causing decreased standing, moving and feather cleaning. Stress also impeded behavioural recovery following treatment.

In some duck housing systems, particularly in cold climates, the ventilation system may be reduced to maintain the temperature. This can affect the microbial aerosol concentration within the environment. High microbial aerosol concentrations (which were associated with poorer hygiene) were found to adversely affect duck welfare and susceptibility to disease (Yu et al., 2016a). Specifically, higher levels of ACTH (which is associated with the stress response) were found in plasma serum and the walking ability of ducks deteriorated in poorer hygiene conditions. Additionally, increasing levels of conditional pathogens such as *E. coli* and *Salmonella* in the caecum increased, whilst probiotics such as *Lactobacillus* decreased in housing conditions with poorer hygiene. In a separate study, it was found that higher concentrations of microbial aerosol in the housing environment also reduced duck immunity, making them more susceptible to disease (Yu et al., 2016b).

Ducks are also susceptible to duck viral enteritis and goose parvovirus, both of which can cause high levels of mortality (Gough and Hansen, 2000; Irvine and Holmes, 2010).

D3.6 Provision of water

The provision of clean water sources such as shallow troughs and drinkers in intensive housing systems (which give ducks the opportunity to dip their heads and splash water onto their body), improves body condition, plumage, foot condition and eye and nostril cleanliness, but to a lesser extent than those allowing full-body access (e.g. showers, baths and deeper troughs). Ducks spend equal amounts of time using troughs, showers and baths but preferred to dabble in the shower and bathe in the bath. When given the choice ducks spend more time in shallower depths (10 and 20 cm) than

deeper pools (30 cm), but perform different behaviours at each depth. Placing water sources directly onto litter adversely affects the welfare of ducks and adequate drainage, maintenance and cleaning is essential.

D3.6a Physical health

Erisir et al. (2009) monitored the growth and welfare of Pekin ducks in intensive housing conditions (indoor only and indoor with an outdoor run) that were provided with and without swimming pools. Body weight was higher at 6 weeks of age when birds were reared with an outdoor run and a pool than those reared without a pool. Food consumption was higher and feed conversion ratio was lower in the indoor, no pool condition. In other studies, the provision of bathing water (i.e. the opportunity to dip their heads and splash water onto their bodies) improved body and plumage condition, along with eye and nostril cleanliness (fewer blocked nostrils) (Jones et al., 2009; O'Driscoll and Broom, 2011). Additionally, foot pad lesions were more severe when ducks were housed with nipple drinkers compared with troughs or bell drinkers (Jones and Dawkins 2010a; O'Driscoll and Broom, 2011). Conversely, one study found that eye, nostril, feather and foot condition was worse when ducks were housed with troughs rather than pin-metered water lines (nipple drinkers) (Schenk et al., 2016). Higher levels of bacteria were found in the water troughs, suggesting poor hygiene could account for the differences between studies.

D3.6b Characteristics of water source

Water sources within duck housing systems include nipple or bell drinkers, troughs, pools, baths and showers. In hot conditions, misters can be used to cool ducks but no peer-reviewed studies were found on the broader welfare implications of this practice. Several studies have documented the effect of the other water sources on the welfare of the birds. In addition to nipple drinkers, Jones et al. (2009) provided groups of ducks with either: a bath in which they had full body access and could swim; a trough in which they could dip their heads and splash water over their bodies; an overhead shower that covered their bodies with a spray; nipple drinkers for the first 5 weeks and a bath thereafter; or nipple drinkers only (control group). Plumage condition was best and the eyes and nostrils were cleaner in treatments which allowed full body access to water (i.e. the bath and shower) and there was no difference in the proportion of time birds spent bathing in baths, showers and troughs, suggesting that troughs and showers provided sufficient bathing opportunities. Similarly, in a study by Waitt et al. (2009) there was no difference in the amount of time ducks spent at most resources (bath, trough, shower) during a bathing bout, except at the nipple at which they spent less time. In this same study however, the behavioural bathing sequence was more variable in the bath or under the shower than at the nipple.

When ducks were given access to all resources simultaneously, they spent most time resting, drinking and dabbling under the shower and preferred to bathe in the bath (although they spent less than 5% of their time doing so) (Jones et al., 2009). In a different study, fewer ducks were found at the water bath than at other resources (trough or bell drinkers), but the authors noted that the bath was used more effectively and efficiently for preening, hence ducks spent less time in it (O'Driscoll and Broom, 2012). It is also possible that as ducks grew, fewer could fit inside the bath at any one time reducing their usage. Overall, ducks were more active in the bath and trough and spent more time idling at bell drinkers.

The importance of the size of the water source provided has been investigated to some extent. Three different sized water troughs (narrow: 15 cm wide and 8 cm deep; intermediate: 20 cm wide and 12 cm deep; wide: 50 cm wide and 8 cm deep) were provided for groups of ducks housed in commercial systems (Liste et al., 2012a). No differences in the health condition of the birds were observed between troughs, except that foot condition was poorer when ducks were given wider troughs. Higher levels of *E. coli* bacteria were found in the wider troughs which may have exacerbated any foot lesions (Liste et al., 2013). In a separate study, the preferred depth of water pools for bathing was investigated, by giving ducks the choice between: a shallow pool (10 cm deep – ducks could stand but not swim); an intermediate pool (20 cm deep – ducks could stand and swim); and a deep pool (30 cm deep – ducks could swim but not stand) (Liste et al., 2012b). Ducks used the 10 cm pool more than the 30 cm pool (64% and 16% of bathing bouts respectively), but there was no difference in their use of the 10 and 20 cm pools. Ducks carried out different activities at different depths, with the deep water being used predominantly for swimming or floating and the shallower water being used for dabbling. Ducks in this study were also reared with shallower water which may have influenced their preferences. The amount of wet preening displayed by ducks was also influenced by the amount of available space at the water source (Jones and Dawkins, 2010b).

D3.6c Management and hygiene

The management of the water source within a duck housing system can have a big impact on welfare. Placement of water resources directly on or over litter can adversely affect both welfare (Jones et al., 2009; O'Driscoll and Broom 2011; Liste et al., 2012a) and production (Allison, 2009, cited by Liste et al., 2012a; Erisir et al., 2009). Even relatively low yielding water sources like nipple and bell drinkers have been shown to result in high levels of litter moisture when placed directly above it (Jones and Dawkins 2010a; O'Driscoll and Broom 2011). Drinkers should therefore be placed in a well-drained area (Allison, 2009, cited by Liste et al., 2012a).

As previously mentioned (section D3.6b) wider troughs were found to have the worst water quality and bacterial content was high, when compared with narrow or intermediate sized troughs (Liste et al., 2013). Cleaning and emptying water facilities at least twice daily may be important for maintaining hygiene levels, but in one study following this routine,

troughs were dirty again within 15 minutes of being cleaned (Schenk et al., 2016). The volume of water and space provided is likely to determine how successful the maintenance schedule is, with smaller volumes becoming dirty more quickly.

Although the provision of open water has generally been found to be better for duck welfare, and to satisfy behavioural requirements, increased mortality in older ducklings provided with large open troughs has been ascribed to contamination (Schenk et al., 2016). Maintaining hygienic conditions remains a significant challenge.

D4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

One study has documented the behavioural time budget of ducks housed in different commercial systems and found that on average at 41 days old they spent 1.5% of their time feeding, 6.7% drinking, 4.2% rooting, 4.6% walking, 15.5% dry preening and 1.8% wet preening (Jones and Dawkins, 2010b). They spent 43.5% of their time relatively inactive and 22% of their time alert. It is important to note that these values represent the average behaviour across all housing systems and that each housing condition may have provided different levels of behavioural opportunity.

D4.1 Behavioural need for a nest

Ducks prefer to lay their eggs in enclosed boxes with a roof and an entrance curtain. The presence of another egg also increases the likelihood of ducks laying within a nest box.

Relatively few studies have focused on the nesting behaviour and requirements of commercially reared ducks. The preferred nesting material of ducks is likely to be different from that of chickens because they naturally inhabit different environments. Most nesting birds however chose a secluded and safe position to lay eggs. In an experimental study, it was found that ducks significantly prefer enclosed nest boxes, opting for those with a closed top and an entrance curtain (Makagon et al., 2011). In the same experiment, ducks showed consistency in their laying pattern across days. It has also been found that ducks are more likely to lay in a nest-box containing an egg (Makagon and Mench, 2011; Makagon et al., 2011). It has been suggested that insufficient nest boxes in duck housing may contribute to increased floor laying (Makagon and Mench, 2011).

D4.2 Social behaviour

Ducks are a social species and when given the opportunity, prefer to perform water-related activities (e.g. preening and dabbling) with other individuals.

Few studies have focused on the social behaviour of ducks within commercial systems. The Mallard however is a gregarious species and there is some evidence that domestic ducks prefer performing certain behaviours with conspecifics. Waitt et al. (2009) examined behavioural synchrony in ducks whilst they performed water-related activities. When given the appropriate space and resource (i.e. troughs, baths and showers), ducks used the resources more socially than when they were provided with only nipple drinkers.

D4.3 Behavioural need for water

Ducks are a semi-aquatic species and water is essential for the performance of certain behaviours such as dabbling, bathing and preening. Preening ensures feathers are kept clean and involves the distribution of water all over the body. Ducks show a preference for water sources which allow increased immersion.

The provision of open water allows ducks to perform multiple behaviours such as dabbling, swimming, head-dipping and bathing, therefore preventing access to open water can have welfare consequences (Rodenburg et al., 2005). Ducks are highly motivated to access open water and will “pay a higher cost” (cross a higher barrier) to access a trough, rather than a nipple or bell drinker (Cooper et al., 2002). Jones et al. (2009) found that when ducks were only provided with nipple drinker lines, they showed compensatory rebound (used the bath significantly more than ducks that had always had access to the bath) when they were provided with a water bath after 7 weeks.

During bathing, ducks will regularly preen their feathers to maintain condition and remove foreign bodies (O'Driscoll and Broom, 2011). Whilst chickens use dry, dust-like material for bathing, ducks require water to ensure a full and effective preening repertoire. Ducks begin a preening bout by immersing the head and wings in water, shaking water over the body and distributing oil (from the uropygial gland) through the feathers. During bathing in pools, it was reported that ducks spent the longest periods of time performing wet preening, followed by drinking and dabbling (although this was performed more frequently) (Waitt et al., 2009).

There is some variation in the amount of time that ducks engage in water-related activities. Jones et al. (2009) found that Pekin ducks spend an average of between 15-22% of their time either bathing, resting on water, drinking or dabbling, whilst Jones and Dawkins (2010b) found that preening alone accounted for more than 17% of the total time budget. In another study, Pekin ducks spent an average of 8.5 hours per day (36% of their time) engaged in water-related activities

(including at pool sides and drinker areas) (Liste et al., 2012b). There is some evidence to suggest that when resources are large enough (i.e. in troughs, baths and under showers), ducks engage in social bathing (Waitt et al., 2009).

D5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

D5.1 System type

The welfare of ducks in commercial systems can be influenced by environmental factors as much as the system itself. Ducklings may be more sensitive to fluctuations in their housing environment than older ducks. Outdoor systems may provide additional behavioural opportunities for ducks.

In a study on the impact of housing conditions on the behaviour and welfare of ducks, it was found that the biggest influencing factors were the environmental measures taken within the house, rather than the housing type or system itself (Jones and Dawkins 2010a; 2010b). In houses where the relative humidity, ammonia and air and litter temperatures were lower, ducks were in better physical condition and had better walking abilities (Jones and Dawkins, 2010a). Additionally, increased panting and wet preening was observed when air temperatures were higher and fewer ducks were seen feeding when litter temperatures increased (Jones and Dawkins, 2010b). Higher relative humidity was associated with increased rest and dry preening. Increased atmospheric ammonia was associated with panting, dry preening and increased activity at the drinker when ducks were at a young age.

Karcher et al. (2013) compared the physical condition of ducks when reared on different flooring during winter; it was found that after 32 days the feathers of ducks housed on raised plastic flooring were in better condition than those reared on litter-flooring. At 32 days, the relative humidity in the litter housing system was higher than in the slatted system and this increased moisture may have contributed to the decrease in feather cleanliness. A similar study was repeated in the summer months and found no differences in feather condition between the two housing systems (Fraley et al., 2013). In contrast, at 7 days of age ducks housed on litter had clearer eyes than those housed on plastic slatted flooring. This may indicate that ducklings are more sensitive to fluctuations in their housing at a younger age.

In a study which compared the growth and welfare of ducks in three different production systems, it was found that ducks engaged in longer preening bouts when reared on plastic net on a bamboo bed compared to those reared with litter flooring (Chen et al., 2015). As a consequence, the feather condition of ducks in the plastic net system was improved. Consideration should be given to the motivation behind the increased preening in the net system, as this may be indicative of a displacement activity in an environment which lacked foraging material.

One study has compared the effect of indoor and outdoor housing systems, with and without a swimming pool, on ducks (Erisir et al., 2009). Ducks that were raised with both a swimming pool and an outdoor area had gained more weight by 6 weeks of age than those reared in alternative conditions. In another study, ducks that were housed indoors spent more time standing, preening, wing and leg stretching, panting, exploring and behaving aggressively, than those that had access to the outdoors (El-Edel et al., 2015).

D6. FEAR AND DISTRESS

Ducks generally find handling and human presence aversive, particularly if the person is unfamiliar. Muscovy ducks are less susceptible to stress than Pekin ducks, but their fear manifests in different ways. Muscovies show increased avoidance responses, whilst Pekins show increased behavioural and physiological activity. Mule ducks are more prone to panicking than the other two strains.

The behavioural and physiological fear response of various duck genotypes has been investigated to some extent. Faure et al. (2003) compared the fear response of the mule duck (a cross between a Muscovy male and a Pekin female) with the responses of their parental genotypes. In this study, tonic immobility tests were conducted and the human flight zone was calculated (as indicators of fearfulness of humans) for all three genotypes. Plasma corticosterone concentration was also measured shortly after tonic immobility testing and before and after restraint in a net. Muscovy ducks generally appeared to be less fearful and less susceptible to stress (had lower levels of corticosterone) than the Pekin duck across most tests. Mule ducks showed intermediate responses for some tests, but were more fearful of humans than both parental genotypes. In similar studies, both parental genotypes were highly fearful, but the fear manifested in different ways (Arnaud et al., 2008; 2010). Pekin ducks showed increased behavioural and physiological activity and Muscovy ducks showed an increased avoidance of humans. Mule ducks panicked and avoided humans more (Arnaud et al., 2008) and were also more sensitive to the social environment compared with the parental genotypes.

Evidence suggests that ducks generally find handling and human presence aversive (Guémené et al., 2006; Flament et al., 2012). Experimental studies have highlighted the importance of ducks becoming habituated to human handlers (Faure et al., 2001), with ducks appearing to perceive an approaching human as a greater threat than an approaching vehicle (Henderson et al., 2001).

D7. SENSORY ENVIRONMENT

D7.1 Light and vision

Lighting within duck housing can have a huge impact on welfare and a range of wavelengths may be important for welfare. Ducklings prefer bright lighting conditions in the range of 6-100 lux and welfare may be adversely affected if ducks are kept in very low lighting (<1 lux).

The lighting used in poultry housing can have a large impact on welfare and production, particularly if birds are continuously housed indoors. It has been suggested that ultra-violet A radiation (320-400 nm) may be of importance (perhaps for migration and orientation) for ducks, given their sensitivity in this wavelength range (Parrish et al., 1981). Different species are likely to have varying lighting preferences and requirements due to their anatomical and natural habitat differences. Unlike chickens, ducks naturally forage underwater and can adjust the refractive power of the eye accordingly (Prescott et al., 2003). Although the specific lighting preferences and requirements of ducks are likely to differ from chickens, a lighting pattern that mimics a natural photoperiod is likely to be preferred (e.g. using dusk-dawn dimming).

Some work has aimed to identify the behaviour of ducks when housed in lighting conditions of different wavelengths and illuminances. Campbell et al. (2015) reared ducks in blue (approximately 425 nm), red (approximately 625 nm) and white light at a standardised intensity and measured aspects of duck behaviour, physiology and condition throughout this period. Few differences were found between ducks raised under red or white light. Ducks reared in blue light however, were more active, had increased plasma corticosterone, and decreased body weight compared with those reared under white light. The authors suggest that ducks reared under blue wavelengths experienced increased stress and that blue light can be detrimental to duck welfare. Conversely, Sultana et al. (2013) found reduced activity and significantly shorter tonic immobility latencies (a potential indicator of their fear response) in ducks in blue light compared with those reared in yellow or white light. These contradictory findings suggest that additional work is required before specific wavelengths can be recommended for ducks.

In another study, the preferences of ducks for different illuminances were investigated. The amount of time ducklings spent in four different light levels was investigated (<1, 6, 20, 200 lux). It was found that ducklings spent most of their time in the three brightest environments (Barber et al., 2004). This suggests that either 6 lux is the minimum preferred light level for ducklings, or that ducklings prefer certain light wavelengths for performing specific behaviours. In some housing systems, it is common practice for producers to reduce lighting levels to avoid outbreaks of feather pecking and cannibalism. The above findings indicate that dim lighting could have adverse effects on welfare and pose behavioural restrictions.

D7.2 Thermal comfort

Ducks can be susceptible to heat stress if they are not able to regulate their body temperature. Water is important for temperature control in ducks and a lack of bathing opportunities can increase the risk of heat stress in hot climates. Duckling incubation temperature can have a profound impact on stress responses in later life.

As with chickens, ducks can be susceptible to heat stress if they are not able to thermoregulate effectively in their housing environment. Ducks use water to assist thermoregulation (Liste et al., 2012b) and a lack of water can be associated with an increased risk of heat stress, particularly in hot climates. The thermoneutral zone for optimal production of Pekin ducks is between approximately 8-22 °C (Cherry and Morris 2008). In a study on the effects of high environmental temperatures on ducks, it was found that a sudden 3-hour increase in brooder temperature from 19 to 37 °C resulted in an increased respiratory rate and body temperature (Zhu et al., 2014). They also found that some internal organs (liver, spleen, bursa of fabricius) were lighter when compared with a control group.

Subtle changes in the incubation environment can also influence physiological processes later in life. DuRant et al. (2010) found that when ducklings were incubated at 35.9 and 37 °C they had higher growth rates than those incubated at 35 °C. In addition, ducklings incubated at the lower temperature had higher basal and stress-induced corticosterone levels.

D8. MANAGEMENT AND HANDLING

D8.1 Stocking density

High stocking densities can result in reduced body weight and increased feather damage.

The stocking density of birds can influence welfare in several ways. One study found that when reared on plastic and wire flooring, a stocking density of 9 ducks/m² resulted in decreased weight gain compared with those kept at lower densities (Xie et al., 2014). The authors suggested that from day 0-14 and from day 14-42, stocking density should not exceed 19 and 8 birds/m² respectively. In a different study, feather damage (which may be the result of feather pecking) was worse when ducks were kept at 8 ducks/m² compared with densities of 5, 6 and 7 birds/m² (De Buisonjé, 2001, cited by

Rodenburg et al., 2005). Conversely, when comparing stocking densities of 7, 9 and 11 ducks/m², it was the intermediate density that gave the best welfare, behaviour, and performance outcomes (Baéza et al., 2003, cited by Rodenburg et al., 2005). This was a small-scale study though and different results may be obtained for commercial flock sizes.

Liu et al. (2015) suggested that dietary tryptophan supplementation at no more than 0.78% could reduce stress at high stocking densities (11 birds/m²). They found higher weight gains when ducks were supplemented with tryptophan but did not measure other indicators of welfare or behaviour.

D8.2 Procedures

D8.2a Bill trimming

Bill trimming, which involves the removal of a portion of the bill, is conducted to reduce feather-pecking within commercial systems. Trimming generally results in ducks engaging in reduced bill-related activities in the first few weeks after, suggesting the procedure may cause pain and damage to the bill. The methods used are variable but tip-searing the bill against a cautery blade may cause less tissue damage than other methods.

Bill-trimming is carried out in some countries to reduce the prevalence of feather-pecking and cannibalism in commercial duck systems. Bill-trimming involves the removal of a portion of the bill using one of the following methods: cold cutting with scissors; tip-searing the bill against a cautery blade for several seconds; or cutting the bill with a hot blade to cauterise the stump (Gustafson et al., 2007a; 2007b). The age and method used across production systems is variable. A few studies have been conducted to compare the impact of different methods, and the age at which it is carried out, on the welfare of the birds (both the impact of the procedure and whether a subsequent improvement in feather quality was seen). In one study, Pekin duck welfare and activity was measured when bills were trimmed (at the hatchery) using the tip-searing and hot-blade methods and compared with a control group in which no trimming took place (Gustafson et al., 2007a). In general, trimmed ducks engaged in fewer bill-related activities and rested more than non-trimmed ducks in the first two weeks post-trim, suggesting that trimming caused acute persistent pain. Both trimming methods resulted in connective tissue proliferation in the bill, but the hot-blade method caused thicker scar tissue and fewer nerve fibres remained in the stump than with the tip-searing method. Additionally, ducks that were bill-trimmed using the hot-blade method were slower to gain weight in the first week after trimming took place. Although duck behaviour suggests that both trimming methods caused acute pain, the feather condition scores of birds in the untrimmed group were worse by 18 days and continued to deteriorate.

The effect of bill-trimming (by cutting without cautery) Muscovy ducks at 20-days post-hatch was investigated by Gustafson et al. (2007b). As was seen for Pekin ducks, in the days following trimming birds spent significantly less time engaging in beak-related activities such as preening, feeding, drinking and exploring and more time resting than non-trimmed birds. After one week, the behavioural differences were no longer apparent, but trimmed birds weighed less than non-trimmed birds suggesting it was painful to feed. No differences in behaviour or weight were observed between treatments at 2 weeks post-trim. The differences in recovery time between Pekin and Muscovy ducks may reflect the different trimming methods used, but might also be due to differences in beak morphology between genotypes. Although beak morphology is remarkably different between species of poultry, similarities exist between the somatosensory systems and it is likely that neural projections are similar (Kuenzel, 2007). Extrapolation of results obtained for other species of poultry may therefore be appropriate (see section LH8.3b).

D8.2b Moulting

Ducks reared outdoors complete their moult more quickly and fully than those reared indoors. This may have implications for feather quality if birds are reared in the absence of natural light.

Moulting is a process which allows birds to replace old feathers with new ones, to maintain their condition. Moulting occurs naturally in wild ducks and feathers are replaced approximately once per year. It has been found that environmental rearing conditions can affect the moulting process. In a study by Butler and McGraw (2009), ducks that were reared outdoors completed their moult more quickly and fully than birds that were housed indoors in high or low quality lighting. Natural, outdoor lighting might therefore be required to regulate moulting and indoor lighting may adversely affect feather condition if moulting is not completed fully.

D9. REARING

Ducks can be reared in a variety of housing systems ranging from slatted indoor units to organic or free-range systems. Ducks are more active when environmental enrichment (e.g. litter, perches, balloons, ribbons) are provided.

There is a large variety in the housing systems used for rearing ducks, ranging from (generally plastic) slatted indoor units to organic or free-range systems which provide access to an outdoor area. A few studies have been conducted on the impact of the rearing environment on the welfare of ducks, but more studies are required on a commercial scale. In an

experimental study looking at the effect of rearing system on production and welfare, ducklings moved and “played” more in a system which provided both sawdust litter and environmental enrichment (perches, balloons and ribbons), compared with those that provided only sawdust or plastic netting over a bamboo bed (no additional details of these housing systems were provided) (Chen et al., 2015). This perhaps reflects the increased behavioural opportunities afforded by the provision of enrichment. In this study, the duration of bathing and feather pecking bouts were longer, but overall feather condition and gait scores were better when birds were net-reared compared with the litter only and enrichment systems. As previously mentioned in sections D3.3 and D3.4, litter quality can influence foot and leg health and may have contributed to the gait differences between the systems.

As has been suggested for laying hens, consistency between rearing and adult housing is likely to be important for ducks. Presenting birds with completely novel resources in their adult environment may increase stress and has the potential to cause injury as individuals may panic or poorly adapt.

D10. BREED EFFECTS

Some breeds of duck cope differently under certain housing conditions. Different fear responses are displayed by Muscovy and Pekin ducks.

In a study conducted by El-Edel et al. (2015), differences between three genotypes of duck were documented when they were housed in indoor and outdoor housing systems. Mulard ducks spent more time lying and less time standing, preening and panting. The authors suggest that the difference in behaviour may be an indicator of the higher fear level that has been reported for the mulard genotype. Mulards however, were more explorative in the outdoor housing condition compared with those reared indoors. Conversely, ducks of the Cherry Valley genotype were more explorative in the indoor rather than the outdoor housing. This may reflect the ability of different genotypes to adapt to different housing conditions.

It has also been shown that Muscovy and Pekin ducks differ in their response to fearful stimuli. In one study, Muscovy ducks generally showed reduced fear and stress responses compared with the Pekin genotype across a range of behavioural tests (Faure et al., 2003). Other studies suggest that Pekin ducks respond to fear and stress with a general increase in behavioural and physiological activity, whilst Muscovy ducks show increased avoidance behaviour (Arnaud et al., 2008; 2010).

D11. WELFARE CONSIDERATIONS: OVERVIEW

Access to a clean water source which allows full (or at least partial) immersion enables ducks to wet preen. Water is also important in hot climates to allow ducks to thermoregulate effectively. Ducks perform different behaviours in different types of water sources (e.g. showers and troughs), thus providing a range of sources is beneficial. A separate drinking source (e.g. nipple line) must be provided. It is also essential that the area surrounding water sources is adequately drained to avoid wet litter which can lead to foot health problems. A high standard of biosecurity is essential as ducks are susceptible to many infectious diseases which may be exacerbated in the presence of open water-sources.

A litter area allows ducks to root and forage but litter quality should be monitored closely to avoid foot health problems.

Ducks are susceptible to stress and can panic easily. Reducing levels of fear within the flock can be aided by walking through the housing regularly. Producers should consider the genotype they are using as some strains are more susceptible to stress.

Ducks are a social species and should not be housed in individual cages. Higher stocking densities have been associated with an increased risk of feather damage and with reduced weight gain, but further research is needed to establish recommended stocking densities, group sizes and sex ratios to ensure good welfare.

Force-feeding for foie gras production causes discomfort, ill-health and increased mortality, and is a serious welfare concern in those countries where it is conducted. The practice is not permitted in Australia.

No scientific literature on the welfare consequences of feather collection in ducks was found but based on their similarities with geese, the collection of feathers from live ducks would be a serious welfare concern. This practice is not permitted for ducks in Australia.

Bill trimming should be avoided unless absolutely necessary. Studies have shown that trimming reduces bill use for up to one week. This suggests the procedure causes pain. Alternative strategies to reduce inter-bird pecking damage including the provision of opportunities for natural foraging behaviour can be implemented to avoid the need for bill trimming.

The provision of natural light (in addition to artificial light) within housing is ideal, but if not possible, a range of light intensities should be provided. Ducks showed a preference for at least 6 lux.

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GEESE

G1. INTRODUCTION

G1.1 Life history

It has been suggested that geese were one of the first animals to be domesticated. Along with ducks and swans, geese are in the family *Anatidae* and are reared for meat, eggs and down feathers. Domestic geese are largely descended from two species: the Greylag goose (*Anser anser*) and the Swan goose (*Anser cygnoides*). The Greylag goose has a widespread distribution from Europe to parts of Asia and Africa. The Swan goose however is limited to specific parts of Asia, hence the majority of breeds are derived from the Greylag. The domestic goose has retained much of the behavioural and morphological characteristics of its wild ancestor (Riddell, 1943).

The Greylag goose is a migratory, semi-aquatic species. The availability of water is important for effective bathing and preening. Their preening routine is elaborate and similar in composition to that of the duck. Whilst some breeds of geese feed on insects, animal and vegetable matter, the Greylag is herbivorous (although goslings may consume a variety of foods including insects) and largely grazes on grass (Ives, 1947). Geese are gregarious and form large vigilant flocks which remain together until the breeding season, when they form long-term monogamous pairs for mating. Mating takes place on open water and geese show strong preferences for nest sites used in previous years (Romanov, 1999). Domestic geese lay larger clutches of eggs compared with their wild counterparts and tend to lay every other day. Whilst wild geese are generally monogamous, domestic geese can be promiscuous if given the opportunity to breed (Appleby et al., 2004).

Geese have a complex social structure and form long-term parent-offspring bonds (Lorenz, 1988, cited by Hemetsberger et al., 2010; Scheiber et al., 2005). Within the flock, a dominance hierarchy exists with family groups out-ranking pairs and individuals (Frigerio et al., 2003). Agonistic interactions (fighting and vocalising) within and between flocks can be frequent.

There is a limited amount of research on many aspects of goose welfare. Geese are closely related to ducks, suggesting a large proportion of the duck welfare literature is also relevant for geese. In some respects, goose behaviour differs from chicken behaviour, for example domestic geese don't typically dust bathe and require water for effective preening. Their behavioural needs in other regards however, are likely to be similar to chickens. Both geese and chickens are natural foragers, roost (Schmitt, 1994) and have complex social groups (Frigerio et al., 2003).

Domestic geese are kept in a variety of housing systems world-wide, ranging from intensive indoor slatted systems to extensive systems providing access to open water.

G2. FEED AND WATER

Geese are natural grazers and good quality fibre and protein are important dietary constituents. Geese may prefer a loose seed-pellet mix over a high-energy pelleted diet. Diet in early life may influence the stress response in later life.

Geese are a rapidly growing species, with goslings reaching almost 3 kg in their first four weeks of life (Farrell, 2004). Greylag geese are primarily a grazing species and little is known about the nutritional requirements of geese in a commercial environment. The influence of the dietary condition in early life on the behavioural and physiological sensitivity of the stress response in later life has been investigated (He et al., 2016). Geese that were fed corn straw silage had a higher post-stress (fasting, catching, transport for 30 minutes) level of methane dicarboxylic aldehyde (a measure of physiological stress response), than geese that were fed steam-exploded corn straw. Although geese have a large caecum, it is suggested that they have a limited ability to digest fibre, particularly if it is of poor quality (Farrell, 2004). The authors indicated that dietary fibre content may have affected the physiological responses of the geese to stress (He et al., 2016). It is suggested that protein is a particularly important dietary constituent for geese (Farrell, 2004).

As geese are natural grazers, the method of feeding in commercial systems may influence their behaviour and welfare. The behaviour of geese was measured when they were fed either a uniform pelleted diet or a diet consisting of a loose mixture of pellets and sorghum whole seeds (Arroyo et al., 2013). The composition of the diets was identical, but feed intake of the loose mixture increased when the amount of time they could access the food was reduced, suggesting they preferred this diet. Consequently, geese fed the mixed diet had a higher body weight at the end of rear.

G2.1 Force feeding for foie gras production

Geese that are reared to produce foie gras are subjected to a period of force-feeding which causes metabolic and hormonal changes. The procedure, which may involve geese being housed in individual crates is associated with the development of pressure sores on the sternum and increased mortality.

In some countries, geese are reared to produce foie gras (fatty liver), although this practice is less common for geese than ducks (Guémené and Guy 2004). Force feeding of geese is prohibited in Australia. The procedure has been described in detail elsewhere (e.g. SCAHAW 1998; Guémené and Guy 2004). Foie gras production involves a period of force-feeding using an oesophageal tube to enlarge the liver up to 10 times the normal size and is associated with a change in metabolism, thyroid hormone release and decreased hepatic blood flow (Bogin et al., 1984, cited by Skippon, 2013; Janan et al., 2000). This process often involves geese being housed in individual pens during force-feeding to make it easier for the handler to perform the procedure. This can result in the occurrence of pressure sores on the sternum (Skippon, 2013). Increased mortality rates are also associated with force-feeding. In an experiment designed to assess whether geese avoided the force-feeding pen, it was found that geese showed no obvious signs of aversion (Faure et al., 2001). It is possible that geese had developed learned helplessness, which is a state an animal can enter if it has learned it is unable to avoid something aversive.

G3. RISK MANAGEMENT

Skeletal problems, which are associated with rapid growth can be seen in domestic geese. Geese are susceptible to several parasitic and infectious diseases, including avian influenza, haemorrhagic nephritis enteritis and parvovirus.

G3.1 Bone fractures and damage

Skeletal problems are found in some species of poultry because of genetic changes and rapid growth. In modern production systems geese are susceptible to tibial deformations and fractures, which generally occur between 6-8 weeks of age (Charuta et al., 2014). In a very small sample of 20 birds, tibial deformations were found in 20% of males and 10% of females (Charuta et al., 2014).

G3.2 Parasitic infections

Myiasis is a parasitic infection caused by fly larvae feeding on wound sites (Farkas et al., 2001). In one study 0.1% geese were infected. Plucking of feathers, along with other skin injuries is likely to increase the risk of infection.

G3.3 Infectious diseases

Geese are susceptible to a number of infectious diseases. As with other species of poultry, access to the outdoors may increase the risk of contact with wild birds that may be carrying infectious diseases such as avian influenza. Haemorrhagic Nephritis Enteritis is a viral disease to which growing goslings are particularly vulnerable and is one the major diseases affecting geese in Europe (Gawel et al., 2014). Goose parvovirus (goose hepatitis) can be fatal and causes high mortality in flocks (Gough and Hansen, 2000; Irvine and Holmes, 2010). Clinical signs include weakness, loss of appetite, diarrhoea and swelling of the eyelids. Similarly to ducks, amyloidosis, a build-up of protein in the internal organs can affect geese and can cause high mortality in infected flocks (Szabo et al., 2000, full text not available).

G4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

Geese have a complex social structure and form strong bonds with individuals within their flock (generally family members). They engage in between- and within- flock agonistic interactions, which they can find stressful.

G4.1 Social behaviour

Geese have a complex social organisation and engage in agonistic interactions (fighting and vocalising) to maintain the structure. Evidence suggests that geese can find these social interactions stressful (Wascher et al., 2008; 2009; 2010). The housing type and stocking density of geese within a commercial system therefore has the potential to hugely affect flock dynamics and goose welfare. In the wild, geese form strong bonds with other individuals and a disruption to the pair bond through predation has been found to induce a long-term (several months) decrease in heart-rate in the surviving partner (Wascher et al., 2012a). In a study a semi-feral population of 120, adult female siblings (that were raised together), rested closer to each other than male siblings or unrelated adults (Frigerio et al., 2001). The authors suggest the bonds might be important for stress reduction through social support.

G5. FEAR AND DISTRESS

Geese find human interactions during catching, handling and transport stressful, particularly if approached by an unfamiliar person. Captive geese were found to have higher stress levels than their wild counterparts, but hand-rearing may reduce the impact of human interactions in later life.

Measures of chronic stress include changes in glucocorticoid hormone metabolites and a decreased immunity. In a study which aimed to identify chronic stress in greylag geese, captive geese had elevated levels of corticosterone and ectoparasites in their droppings, compared with groups of wild geese in a similar location (Scheiber et al., 2015). The level of ectoparasites found in the faeces is thought to reflect a decreased immunity. Despite the comparative difference in corticosterone levels, values were still relatively low in all geese and were not, as described by the authors, at a pathological level. The geese were housed in fairly low numbers and had outdoor areas with pools, so different results may be observed for geese housed in intensive commercial systems.

Agonistic encounters have been shown to induce an elevated heart-rate in geese compared with other behaviours such as feeding or preening, despite displaying similar activity levels (Wascher et al., 2008; 2009). In addition, heart rate increases were found to be greater when interactions were more intense and when repeated agonistic interactions occurred with a specific individual (Wascher et al., 2009) and they induced stress-related behaviours such as body shaking, increased vigilance and auto-preening (Wascher et al., 2010). These results suggest that agonistic social interactions may induce acute stress responses in geese and that group composition might influence the intensity of the response. In another study, it was found that faecal parasite load was higher in geese that were goose-reared, rather than those that were hand-reared and then raised in an experimental housing system (Wascher et al., 2012b). In a different experiment, hand-reared goslings also had lower levels of faecal glucocorticoid metabolites (associated with the stress response) following exposure to three potential stressors: a high social-density feeding situation; predator exposure; and handling (Hemetsberger et al., 2010). Both results suggest that hand-reared geese coped better with stressors encountered in a managed system.

In addition to social interactions, geese experience heart-rate changes, which might be indicative of an acute stress response in other challenging situations. Catching and handling, a model predator and approach by a human have all been found to evoke an elevated heart rate (Wascher et al., 2011; Toth et al., 2012, full text not available). The greatest increase was seen when geese were approached by an unfamiliar human, indicating the importance of habituation to humans prior to handling.

In a study which measured the behavioural and physiological effect of catching and transporting geese to slaughter the blood concentration of superoxide dismutase dropped by 14% and creatine kinase levels increased (both are associated with the stress response) by 186% after stress (post-stress vs. pre-stress), which suggests the process was stressful (He et al., 2016).

G6. MANAGEMENT AND HANDLING

High stocking densities may lead to an increase in bone deformations, hence lower densities are better for welfare. Feather plucking from live birds takes place in some countries and can cause severe welfare issues.

G6.1 Stocking density and group size

A few studies have investigated the effects of stocking density on geese. In one study, geese were reared on slatted flooring at stocking densities of 4, 6 or 8 geese/5 m² and it was found that body weight was higher when geese were kept at the lowest stocking density (Chang et al., 2010, full text not available). This finding was replicated in another study, but the differences were particularly marked when geese were less than 4 weeks of age (Lin et al., 2016). This study also reported the incidence of a condition known as angel wing. Angel wing is a deformation of the carpometacarpus or the joint between the third and fourth metacarpals in the wing, causing the bone to twist away from the body. This condition may be influenced by several factors, including the amount of space provided for movement and stretching of wings for healthy development. In the aforementioned study, angel wing was observed at all stocking densities tested and averaged 42% across treatments by 14 weeks of age. The authors suggest that alternative stocking densities may reduce angel wing in geese, but that other factors such as genetics and nutrition also play a role.

G6.2 Procedures

6.2a Moulting, feather gathering and live plucking

Feathers from geese are used in the down industry and are either collected at slaughter or, in some countries (where legal), are collected from live birds. EFSA (2010) drew a distinction between feather gathering where feathers that are loose due to natural moulting are removed using a brushing or combing action, and plucking where at least parts of the targeted feathers are pulled out from the breast, belly, flanks and back.

Domestic geese moult more regularly than their wild counterparts and the feathers are mature by 10 weeks, after which the first moult begins (Kozak, 2010). Feathers may be collected for commercial purposes up to 3 times during the first year of rear, and can be collected from birds kept for egg, meat or foie gras production. Very careful feather gathering at the time of each natural moult may not cause substantial pain or distress (Kozak, 2010) but live plucking leads invariably to bleeding follicles, and is most likely (based on work on feather removal in laying hens) accompanied by a sensation of pain (EFSA, 2010). Live plucking can also result in significant wounds and bruising (Farkas et al., 2001; EFSA, 2010). Live plucking is also a risk factor for fly-borne infections (Farkas et al., 2001). There have been many exposés of live bird plucking that show birds sustaining significant skin wounds during rough manual plucking or (in some non-European countries, e.g. China) during machine plucking of feathers (Kozak, 2010). EFSA (2010) concluded that, under commercial conditions, feather gathering could not be fully distinguished from feather plucking. Feathers ripen at different times on different body regions and between different individuals. Thus, whilst some ripe feathers can be gathered, the pressure to harvest all useable feathers at one time will necessarily mean that many feathers are plucked. EFSA (2010) concluded that the catching, handling and restraint of birds for feather collection was also likely to cause stress (geese are more susceptible to stress during moulting periods) and had the potential to cause injuries, including dislocations, and suffocation. Live plucking is not permitted in the EU, but feathers can be collected from birds at the slaughterhouse.

G7. REARING

Increased body weight may be found in more intensive housing systems, but this may be reflective of reduced behavioural opportunities.

In some countries, geese can be either naturally- or artificially-hatched. A study found no effect of rearing system (intensive or free-range) or hatching condition on the body weight of geese (Boz et al., 2017). In contrast, it has been found that the body weight of geese was higher in a wire-floored, intensive system compared to other systems, including free-range (Liu et al., 2011; El-Hanoun et al., 2012). Body weight is not a definitive marker of welfare however, and it is likely that intensive systems result in increased body weight as a consequence of reduced behavioural opportunities. These studies measured few other physical and behavioural indicators of welfare. In one study, more wounds were found on geese that were reared indoors, compared with those in a free-range system (Boz et al., 2017).

G8. BREED EFFECTS

Certain breeds or genetic lines might be more likely to develop bone deformities.


Angel wing is a condition which prevents normal wing development. Some species of geese are more susceptible to developing this condition, but certain lines within a breed (e.g. White Roman geese) have also been found to be at an increased risk (Lin et al., 2016).

G9. WELFARE CONSIDERATIONS: OVERVIEW

Geese are adapted to eat a varied diet with a large component of fresh material obtained via grazing. They should be fed a diet that provides some variety and provided with a litter area that enables foraging behaviour. Diets should be provided that enable healthy, but not excessive growth rates to avoid musculo-skeletal problems.

Research is needed to establish minimum stocking densities that promote health and avoid the occurrence of conditions such as angel wing. Research is also needed to establish group compositions that ensure welfare, because adult geese (unlike the chicken) form strong bonds with specific individuals. Geese are a species with a complex social structure and should not be housed in individual cages.

Geese are susceptible to stress and can panic easily. Producers can reduce levels of fear within the flock by positive early handling and rearing strategies, and by regular gentle walking to allow flocks to habituate to human presence. Producers should consider the genotype they are using as some strains are more susceptible to stress than others.



Research is needed to establish whether water should be provided to allow geese (as for ducks) the opportunity of wet preening.

Force-feeding for foie gras production causes discomfort and ill-health and raises serious welfare concerns in those countries where it is conducted. Geese that are individually crated will be unable to express any of their behavioural needs. This practice is not permitted in Australia.

The plucking of feathers from live geese causes injury and increases susceptibility to infection and is a serious welfare concern. Since it is difficult to distinguish feather gathering from plucking, to ensure bird welfare feathers should be collected only from dead birds at the slaughterhouse.

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TURKEYS

T1. INTRODUCTION

Turkeys are omnivorous birds with complex social structures maintained by aggression. Despite their larger size they are similar in behaviour to their smaller poultry counterparts, engaging in nest building behaviour, dust-bathing, foraging, perching and roosting.

T1.1 Life history

Wild turkeys were abundant in North America when the first Europeans arrived approximately 500 years ago (Brant, 1998). The seven varieties, from two species, present then still survive wild in the US today and are popularly hunted gamebirds in most states (Brant, 1998). Wild turkeys eat a combination of animal matter and vegetable matter with the largest proportion of their diet being plant based in origin (Dalke et al., 1942). Food choice varies over seasons to reflect food availability: the animal matter consumed is predominantly insects, typically beetles, grasshoppers and ants, while the vegetable matter encompasses a range of fruit and seeds, with grass seeds and blades and acorns being most important (Dalke et al., 1942).

Wild turkeys live in flocks with a highly competitive social system; the males form a strict hierarchy, established by aggressive interactions, which is contested throughout the year (Buchholz, 1997; Buchwalder and Huber-Eicher, 2003). Agonistic interactions between males start when they are juveniles establishing dominance hierarchies amongst their siblings and age cohorts and continue throughout their lives (Buchholz, 1997). Male sibling groups display at traditional lekking (competitive display) sites during the breeding season, with the dominant male of the dominant group doing most of the mating (Buchwalder and Huber-Eicher, 2005a).

Female turkeys prefer cover that is complex and highly variable in habitat structure (Badyaev, 1995). As nest predation is a common source of breeding failure in some wild turkey populations, wild turkeys select nest sites with dense understory (shrubs and grasses) and visual obstruction (logs and rocks), however, such sites are often limited in availability (Badyaev, 1995). Nests are often located at forest edges or alongside roads, probably because of the variety of resources these sites offer incubating females as well as the increased understory density (Badyaev, 1995).

Like other poultry species, wild turkeys can fly (although their range is limited), engage in frequent dust-bathing (Sainsbury and Sherwin, 2001), and make use of environmental perches, particularly to roost on at night (Bessei, 1999, cited by Martrenchar et al., 2001).

During the 500 years of their domestication, a number of new varieties of turkey have been developed, however, until recently these were selected for aesthetic characteristics rather than for meat production and conformation (Brant, 1998). Since production became a greater focus of breeding efforts, two major changes have been seen within the commercial flock. Firstly, consumer demand has led to the majority of commercial flocks being bred to have white feathers instead of the turkeys' naturally darker plumage, to prevent dark spots on the carcass (Brant, 1998). Secondly, the selection for big breasted birds has resulted in fertility issues with their size impeding their ability to successfully mate; consequently commercial flocks are routinely bred by artificial insemination (Appleby et al., 2004).

Turkeys have been the subject of intense (and ongoing) selection pressure for increased growth rate. Each year new, faster-growing strains are available meaning that research findings relating to nutritional requirements and musculoskeletal health (in particular) can rapidly become outdated. Commercial breeds such as the Aviagen 'B.U.T. 6' and the Hendrix XL attain weights of approx. 10.5 kg at 15 weeks (females) and 24.0 kg at 22 weeks (males).

www.aviagenturkeys.com/en-gb/products/b-u-t-6

www.hybridturkeys.com/en/

More recently the focus has been on feed efficiency rather than fast growth which may result in emerging welfare problems, for example hunger may become more prevalent.

Domestic turkeys are primarily farmed for their meat, with turkey breeding establishments supplying poults for the meat rearing systems. Scientific research has focused on meat rather than breeding birds. Consequently, this review will focus on the welfare of meat turkeys unless otherwise stated. Unlike the broiler industry, the meat turkey industry has a large seasonal component and this can greatly impact the environment the birds are kept in, their husbandry, and consequently their welfare.

T2. FEED AND WATER

The diet of commercially reared turkeys has received a lot of research attention, principally in relation to the effects of various constituents and mineral supplements on performance and their association with common diseases in meat turkey production.

Turkeys are highly social birds and feeding and drinking, along with many other behaviours, are socially facilitated (Sainsbury and Sherwin, 2001). This tendency means that it is important to ensure that there is sufficient space at troughs and drinkers to allow multiple birds to use these together.

Turkey poults receive successive changes in diet during rearing as their beak size and nutritional requirements change. One of the biggest dietary changes they experience is the transition from crumbs to pelleted food. Initially this change is accompanied by a reduction in feed intake and an increase in exploratory behaviour, with different individuals showing differing levels of sensitivity to feed change (Lecuelle et al., 2010).

Soybean meal is the main source of dietary protein for commercial turkeys (Youssef et al., 2011a). Protein provision was previously considered a risk factor for foot pad dermatitis (FPD), although this has now been proved unfounded (Youssef et al., 2011a).

The impact of feeding different dietary constituents on the health and welfare of turkeys has received research attention since commercial production began. Feeding whole grains as part of the commercial diet appears to generate conflicting results and the impact the whole grain constituent has on the bird's growth and well-being depends on the level at which it is fed. Growth rate shows little or no depression when birds are fed 20% whole barley, however, once this increases to 35% an adjustment period is required during which there is a reduction in growth and feed efficiency (Bennett et al., 2002). However, if a high level of whole barley is fed before 40 days of age, turkey toms show improved livability and skeletal health due to the reduction in early growth rate (Bennett et al., 2002). Diluting standard diets with whole grain wheat was found to have no influence on proportions of breast muscles, leg muscles and fat in turkey carcasses; however, feeding low levels was associated with less severe symptoms of FPD and increased the dry matter concentration of excreta (Jankowski et al., 2012b; 2013). Feeding higher levels of whole wheat may negatively impact body weight gains and feed conversion ratios (Jankowski et al., 2013). Feeding grit does not seem to be essential if birds are being fed whole grains (Bennett et al., 2002). Hocking et al. (2013) explored the growth and skeletal responses of supplementing turkeys with riboflavin and biotin. Poults with no supplemental riboflavin had poor gait scores and higher cull rates, as did those only supplemented with biotin. Bones of poults on both supplements were larger, stronger and denser, but riboflavin deficiency was more detrimental.

Maintaining high litter quality is of particular importance in turkey production (see T5.1a), and dietary adjustments have been explored to see if litter improvements can be made through dietary interventions. Litter quality can be indirectly improved by feeding supplements such as silicon dioxide, which has also been demonstrated to improve turkey body weight and the efficiency of feed conversion (Tran et al., 2015). However, some feed ingredients, such as distillers dried grains with solubles, canola meal and chloride have been found to increase litter moisture content (Farahat et al., 2013b), and it is likely that the effect of chloride on litter moisture accounts for the relationship seen between chloride and foot pad score (Farahat et al., 2013a). These ingredients should be avoided or minimised where possible to maintain high litter quality.

Aflatoxins are common contaminants of poultry feed and feedstuffs and turkeys are one of the most sensitive poultry species towards this group of fungi produced mycotoxin (Diaz et al., 2009). Mycotoxin exposure can compromise immune response, weight gain and therefore productivity, and may lead to death in some instances (Diaz et al., 2009). Feed additives are available that can successfully ameliorate the adverse effect of aflatoxins, suppressing mortality and correcting the immunological alterations that arise through aflatoxin exposure (Diaz et al., 2009).

Given the restrictions on antibiotic usage, nutritional and non-nutritional approaches to counteract the debilitating effects of stress and infection are being explored as alternative solutions (Huff et al., 2004). Providing vitamin E or sodium salicylate can modulate the inflammatory response, reducing the effects of bacterial exposure in challenged birds; however the negative effect on body weight of non-challenged birds suggests their use should be limited to predictable times of stress in the production cycle e.g. moving, handling or disease outbreaks (Huff et al., 2004). Yeast supplementation may provide protection against clostridial dermatitis (CD) when CD risk increases at the latter stages of production (Huff et al., 2014). Antibiotic usage can also have negative effects on gut health in turkeys, but probiotics have been suggested as a viable alternative to subtherapeutic antibiotic use (Danzeisen et al., 2015).

Poults appear to drink more water in the morning (7-10am) compared to other times of day, and drinking behaviour accounts for approximately 2% of the time budget (Busayi et al., 2006). Water consumption appears to be unaffected by the humidity of the environment or the foot health status (Hocking and Wu, 2013). Type and density of water providing equipment may cause crowding and spillages in some areas, especially if birds need to compete for access (Martrenchar et al., 2002). In a study of French turkey flocks, 79% of houses were equipped with bell drinkers and 21% with nipple

drinkers with drip cups underneath. These were provided at low densities of <0.05 bell/m² or <0.2 nipple/m² (44%), intermediate densities of 0.05 to 0.2 bell/m² (28%), or high densities of >0.2 bell/m² or >0.8 nipple/m² (28%). Problems with foot health were increased at the lowest densities of water equipment (Martrenchar et al., 2002) (see T3.7).

Turkey breeder birds are subject to restricted feeding practices to the same extent as broiler breeders, and consequently their welfare will be similarly compromised. Restricted feeding practices in turkey breeder birds do not appear to have received a great amount of research attention since the early 1990s.

T2.1 Relationships with injurious pecking

Insufficient dietary fibre and a lack of foraging opportunities have been implicated in feather pecking and cannibalism in turkeys (Dalton et al., 2013). Increasing the fibre content of feed and converting from pellets to mash has been shown to increase the proportion of time spent feeding and reduce the proportion of birds with damaged feathers (Hale and Schein, 1962, cited by Hughes and Grigor, 1996). There is also evidence that providing high fibre foraging substrates, such as rough cut wheat straw reduced the number of pecking injuries seen on the wing, tail and head (Sherwin et al., 1999). In terms of the relationship between diet and injurious pecking, the emphasis seems to be on increasing the time spent eating and providing foraging opportunities, rather than addressing nutritional imbalances through dietary adjustments. For turkeys at least, it appears that other factors such as light quality and intensity may have a greater influence on this behaviour than food content.

T2.2 Relationship with skeletal health

The contribution various feed supplements can make to skeletal strength and bone health has been investigated extensively. The biomechanical properties of bone can be improved by mineral supplementation, and increased bone strength should result in fewer broken bones in commercial turkey production (Ferket et al., 2009).

The occurrence of leg problems in toms grown to a heavy market weight (>18 kg) may be influenced by dietary levels of calcium and nonphytate phosphorus (nPP) (Roberson, 2009). There is a lack of published data on which to base recommendations for dietary calcium and non-phytate phosphorus (nPP) (the phosphorus that is potentially utilisable by the turkey) for modern fast growing commercial breeds and data are often conflicting (Roberson, 2009).

Phosphorous, and to a lesser extent calcium, requirements in turkey production are believed to be considerably greater than the USA's National Research Council (NRC) recommendations in 1994 (Atia et al., 2000). Roberson (2009) examined the effects of feeding NRC recommendations of dietary calcium and varying levels of nonphytate phosphorus (nPP) in four treatments (LOW, ending with 0.25% nPP at 19 weeks of age and formulated according to NRC guidelines; MED, 0.06% units above LOW; HIGH, 0.10% units above MED; VERY HIGH, 0.10% units above HIGH). Bone integrity (and growth) was greatest for the birds fed the HIGH and VERY HIGH diets (Roberson, 2009). Reported increases in spontaneous femur fractures in commercially grown toms illustrates the need for further research to be conducted (Roberson, 2009). Diets insufficient in phosphorus can result in hypophosphatemia which can lead to foot problems and fractures in the extremities in the fast growing period (to 16 weeks of age) of turkeys (Özkan et al., 2012). Adding phosphorus and vitamin D3 to the food or water of turkeys at approx. 14 weeks of age had beneficial effects on biochemical parameters and partially relieved symptoms of hypophosphatemia (Özkan et al., 2012). However, to ensure turkey welfare it is far better to adopt a preventive approach and ensure adequate nutrition throughout life. The importance of adequate phosphorus and calcium intakes for modern, fast-growing strains has been recognised by some commercial breeding companies and revised guidelines were published in 2015 by Aviagen. However, there are also pressures to reduce feed costs and litter moisture and for these reasons, Hendrix reduced the recommended calcium and phosphorus concentrations in their nutrient guidelines for turkeys by 5-10% in 2013.

Dietary supplementation of organic trace minerals (Zn, Mn and Cu) as complexed with methionine hydroxy analog along with selenium yeast (Mintrex P_{Se}) can reduce the incidence of leg abnormalities associated with rapid growth, such as varus, valgus and shaky leg (Ferket et al., 2009). However, results are not always consistent, with one study finding no strong relationship between dietary calcium and bio-available phosphorus concentrations and the prevalence of tibial dyschondroplasia (TD) (Hocking et al., 2002).

Dietary deficiency of riboflavin and biotin has been associated with growth retardation, neurological, skeletal and skin abnormalities in turkey poults (Hocking et al., 2013). Peripheral nerve disruption in riboflavin deficient poults ultimately leads to an inability to walk (Hocking et al., 2013). Increasing supplementary biotin when no supplementary riboflavin was provided was associated with a reduction in tibia weight, density, strength and stiffness; all poults fed on diets without supplementary riboflavin were prematurely culled on welfare grounds before the end of the study (Hocking et al., 2013). Biotin supplementation to reduce FPD has shown mixed results and may only be effective if litter quality is also maintained (Mayne et al., 2007a; Youssef et al., 2012).

The dietary intake of sodium chloride (salt) needs to be carefully balanced in turkeys; receiving too little can result in reduced tibia strength, while receiving too much can negatively affect caecal metabolism (Jankowski et al., 2012c). Low sodium can also impede growth and feed utilisation (Jankowski et al., 2012a).

These findings highlight the complexity of using diet to address musculoskeletal issues. The interactions that can arise internally between individual nutritional supplements, and externally with environmental factors such as litter quality indicate the potential consequences for the welfare of the turkey should any of these factors be suboptimal or out of balance.

T2.3 Free range and organic diets

Turkeys on pasture spend the majority of their time grazing (Karabayir et al., 2008). High performing birds such as turkeys can be difficult to feed in organic systems. This is primarily because the restrictions defined by organic production schemes make it very hard to feed the birds the amino acid content they need to support their growth requirements (Zollitsch and Baumung, 2004). Organically grown turkeys deficient in amino acids may display severe growth depression, variable body condition and ultimately feed refusal (Zollitsch and Baumung, 2004). Conventionally fed growing turkeys have their protein needs met through the addition of soybean, potato protein and yeast to their compound feed, but these protein sources are not always available from organic sources and may be perceived as too costly to include if they are available (Zollitsch and Baumung, 2004).

T3. RISK MANAGEMENT

Farmed turkeys are at risk from numerous sources of welfare compromise. Some of these, for example musculoskeletal disorders, arise from the extreme selection pressures that have been applied to commercial birds for disproportionately large breasts and excessive growth rates. Others may arise due to the way they are managed within the farm system, for example foot pad dermatitis, injurious pecking, and breast blisters and buttons.

T3.1 Mortality

Poult mortality is a costly problem to the turkey industry, particularly for poult suppliers (Carver et al., 2000; 2002a). For the first 14 days of life, the patterns of mortality in hen and tom poult flocks are similar with greater mortality in the first 7 days than in the second week, although the levels of mortality are different with toms experiencing higher mortality levels (median mortality across companies 1.27 to 5.76%) than hens (median mortality across companies 0.98 to 2.11%) by day 13 (Carver et al., 2000). Causes of poult mortality are multifactorial, with effects differing across strains and between sexes and hatcheries amongst other factors, making addressing these issues a complex task (Carver et al., 2000).

T3.2 Causes of mortality

One observational study identified hatchery associated risk factors for poult mortality (Carver et al., 2002a). For hen flocks mortality risk factors included the truck on which poults were shipped, truck temperature (low temperatures increasing the odds of mortality) and the number of poults dead on arrival at the placement farm (higher odds of mortality associated with higher numbers of dead on arrival) (Carver et al., 2002a). In contrast, risk factors for tom flocks included desnooding (lower risk associated with birds with snoods removed), truck temperature and shipping time (an increase of both temperature and time associated with higher odds of mortality), and weather conditions at placement (placement during icy weather reduced the odds of mortality, while placement on a cloudy day raised them (Carver et al., 2002a). Intervention studies are required to fully understand and interpret these complex relationships.

T3.3 Musculoskeletal disorders

T3.3a Musculoskeletal disorders and growth

The bodyweight of modern broad-breasted turkeys increases considerably within a very short space of time during the growing period (see T1.1), with a disproportionate increase in the breast muscles (Buchwalder and Huber-Eicher, 2005b). This high growth rate has been associated with an increased incidence of musculoskeletal and other structural and physiological imbalances in modern commercial breeds (Da Costa et al., 2014), as the selection for higher body mass has been made without the corresponding increases in musculoskeletal integrity (Dalton et al., 2016). Due to their faster growth rate and heavier final weights, toms are more greatly impacted by growth related disorders than turkey hens (Vermette et al., 2016). Male turkeys show a biphasic pattern of growth caused by the differential growth of different organs (bone and tissue in the first phase, and mainly muscle tissue and the reproductive systems in the second (Hurwitz et al., 1991, cited by Yahav et al., 2008).

Disorders of the skeletal system in turkeys cause significant economic losses and impact on the bird's quality of life (Özkan et al., 2012). The proper function of the skeletal system plays an essential role in animal welfare (Tatara et al., 2006). Leg problems, including lameness, bone developmental disorders and bone breakage, are a primary concern for turkey producers worldwide (Ferket et al., 2009). The change in body conformation as modern commercial turkeys have been selectively bred for large breast muscles has shifted their centre of gravity forward, affecting gait and subjecting the femur and tibia bones to considerable stress and strain, affecting bone development (growth and mineralisation) and increasing the risk of fractures (Tatara et al., 2006; Ferket et al., 2009). In the mid-1960s the market weight of a 16 week

old turkey was 6 kg, this increased to nearly 13 kg by the end of the 1990s and by the mid 2000s market weight of commercial toms could exceed 26 kg (Tatara et al., 2006). In the past decade, breeding goals appear to have been adjusted with a reduced focus on further increases in target weights (see T1.1) but more emphasis on other factors such as feed efficiency.

T3.3b Musculoskeletal disorders and lameness

In commercial flocks, lameness is a leading cause of reduced productivity and welfare (Dalton et al., 2016). As turkeys age, their activity levels decrease and their time-budget changes, thought to be due in part to increasing musculoskeletal weakness (Sherwin and Kelland, 1998). There are numerous musculoskeletal disorders that can lead to impaired movement and lameness in turkeys; these include crooked/deviated toes, inflamed or infected leg joints, fractures and deformities of the leg bone and associated cartilage, tissue lesions and contact dermatitis of the hocks or foot pads (Dalton et al., 2016). The genetic contribution to these problems was highlighted in a study by Eusebio-Balcazar et al. (2015). Four strains of turkeys (two proprietary Aviagen lines, and two commercial strains, Nicholas 85 and Nicholas 88) were examined for differences in long bone development. Each strain had different leg problems ranging from twisted legs, to valgus and crooked toes, but the gait scores among the strains at 15 and 18 weeks were not different.

A comparison of the behaviour of birds treated with the analgesic butorphanol and control birds found that treated birds spent significantly more time putting weight on their legs than control birds which spent more than half the observation time lying on the floor (Buchwalder and Huber-Eicher, 2005b). This and other evidence suggests that affected turkeys are likely to experience chronic pain (Dalton et al., 2016) and compromised access to resources such as food and water (Vermette et al., 2016).

T3.3c Tibial dyschondroplasia (TD)

Tibial dyschondroplasia (TD) is a metabolic disease affecting the growth of bone and cartilage in young poultry. There is evidence that TD can be widespread within a flock without being visible through gait abnormalities (Hocking et al., 2002). Experimentally, TD was rare in poults from a commercial heavy male line prior to 10 weeks of age, but incidence increased to 71% by 13 weeks, with the most severe lesions and highest TD incidence in those birds fed diets most closely resembling the calcium and phosphorus concentrations of commercial rations (Hocking et al., 2002). The relevance of high TD incidence on the welfare of turkey requires further investigation. The absence of visible gait abnormalities may reflect limitations in the assessments used (Hocking et al., 2002). Furthermore, evidence suggests that TD lesions function as foci for the development of osteomyelitis (Wyers et al., 1991, cited by Hocking et al., 2002), a common cause of long bone necrosis in turkeys.

T3.4 Injurious (severe) feather pecking

In contrast to the body of information available on injurious pecking in laying hen (see LH3.5), far less information exists on feather and head pecking in turkey flocks, particularly in a commercial setting (Duggan et al., 2014). Injurious pecking in turkeys can be classified into three distinct forms: head pecking, severe feather pecking and cannibalism based on how these behaviours differ in their development, causation and targeted areas (Dalton et al., 2016). Head pecking is typically directed at the head, snood and neck of the targeted turkey and is considered an act of aggression (Buchwalder and Huber-Eicher, 2003; Duggan et al., 2014; Dalton et al., 2016) (see T3.5 and T4.5). Severe feather pecking and cannibalism are thought to have a different aetiology, representing re-directed foraging due to a lack of environmental complexity (Martrenchar, 1999; Sherwin et al., 1999; Duggan et al., 2014; Dalton et al., 2016). It has been suggested that both feather pecking and cannibalism occur due to deficiencies of the environment in which turkeys are housed and their inherent tendency to peck (Dalton et al., 2013). Environmental deficiencies, for example a lack of appropriate substrate for foraging or investigating, nutritionally unsuitable diet or inappropriate feed form, mean that the turkeys are unable to perform their full behavioural repertoire (Dalton et al., 2013) and their motivation to peck is redirected.

Feather pecking that results in significant bodily injury resulting in carcase damage or downgrading or even death is a significant economic and welfare problem in the commercial turkey sector (Busayi et al., 2006). There appears to be a sex difference, with female birds showing a reduced prevalence of this behaviour in comparison with male birds (Busayi et al., 2006).

The relationship between the lighting environment of farmed turkeys and injurious pecking is complex. Turkey poults have plumage markings that are visible under UV light. The age and sites at which these marks first occur corresponds to the onset and location of pecking commonly observed amongst commercial turkey poults, leading to the hypothesis that the restrictions in the birds' lighting environment (see T7.1) and hence their distorted perception of these markings has led to the development of this behaviour (Sherwin and Devereux, 1999). The intensity of the light environment as well as its spectral range may also have an influence on feather pecking. Commercial turkeys are typically maintained at low light intensities to reduce the risk of feather pecking which is observed at greater levels in birds exposed to daylight or bright artificial lighting (Barber et al., 2004). However, effective enrichments can reduce the incidence of injurious pecking even when turkeys are kept under fluorescent lights at 10 lux (Moinard et al., 2001).

There is an intriguing relationship between feather pecking propensity and genetic line. One study found a higher level of strong feather pecks and pulls in a traditional line than a selected male line, however, there were no injuries in the traditional birds in contrast to the selected line (Busayi et al., 2006). This indicates that traditional birds are physically and/or behaviourally more able to cope with the threat of feather pecking either through their feathers being harder to remove or break, or by moving away from the pecking bird or submitting to it more quickly (Busayi et al., 2006).

As discussed in T2.1, investigations of the relationship between dietary factors and feather pecking in turkeys has revealed correlations between diet form, frequency and content, and feather pecking behaviour (Dalton et al., 2013). But the discrepancies between studies demonstrate the importance of providing dietary forage and foraging opportunities in an appropriate format for the turkeys or no improvement in feather pecking is seen (Sherwin et al., 1999; Dalton et al., 2013).

Limited information on the use of environmental enrichment to reduce feather pecking in turkeys exists (Duggan et al., 2014). If used, the success of such enrichment may be dependent on the novelty of the item and the age at which it is introduced; turkey poults as young as 2-4 weeks of age have been observed with pecking injuries suggesting that providing enrichment to poults rather than in the grower barns may be more effective (Duggan et al., 2014). One study did not detect a reduction of pecking straw and enrichment objects with age, suggesting that changing enrichment items to maintain novelty, and consequently attract redirected pecks, is not always necessary (Martrenchar et al., 2001). The studies that have been conducted suggest that providing environmental enrichment can improve turkey well-being through a reduction of injurious pecking activity (Martrenchar et al., 2001).

It has been observed that birds that behave differently to the rest of the flock, for example because they are ill or lame, may become preferred targets for injurious pecking activity (Dalton et al., 2013). Lameness and pecking injuries both increase over time in commercial turkey flocks, however it is unknown whether this represents a causal relationship or is simply a temporal association (Dalton et al., 2016) and certainly warrants further investigation.

T3.5 Aggression

The severity of aggressive encounters and injuries due to head pecking can result in death or mandatory culling in commercial fattening units (Buchwalder and Huber-Eicher, 2003) and is consequently a serious economic and animal welfare concern (Buchwalder and Huber-Eicher, 2004).

Wild turkeys establish their dominance hierarchies by aggressive encounters, however unlike in domestic settings, fights between wild birds typically end without serious injury occurring (Buchwalder and Huber-Eicher, 2004). Consequently, environmental factors such as feeding, management and housing, and endogenous factors such as genetic disposition linked to domestication have been suggested to explain the difference between the behaviour of wild and domesticated turkeys, kept in commercial fattening units (Buchwalder and Huber-Eicher, 2004).

The high injury rates seen in commercial settings may be because the high stocking densities mean that there is insufficient room for birds to retreat far enough away to avoid aggressive encounters (Buchwalder and Huber-Eicher, 2004).

Levels of aggressive pecking in turkeys on pasture is low in both bronze and white turkeys, although the level seen in the white birds was significantly higher than that observed in the bronze (Karabayir et al., 2008), suggesting that increased aggression may have been bred into modern strain along with the change in plumage colouration.

T3.6 Breast blisters and breast buttons

Breast skin alterations in turkeys can occur in numerous forms (Mitterer-Istyagin et al., 2011). 'Breast blisters' are encapsulated areas of swelling which may be filled with serous fluids (hygroma) or pus (bursitis sternalis) and are associated with staphylococcus and coliform infection; in contrast breast buttons are a sign of focal ulcerative dermatitis (Mitterer-Istyagin et al., 2011). The presence of these skin alterations is an economic concern as affected areas, or even entire carcasses may be discarded depending on the level of associated inflammation (Mitterer-Istyagin et al., 2011). The presence of inflammation is also likely to reflect some degree of pain in affected birds, further reducing welfare.

Male birds are more frequently diagnosed with breast skin alterations, perhaps due to their greater body weight leading to greater pressure on the breast when lying and longer lying times (Mitterer-Istyagin et al., 2011). There is also evidence of a breed difference in propensity to develop breast alterations (Mitterer-Istyagin et al., 2011).

The aetiology of these pathological skin alterations is multifactorial, and health status seems to be determined by a complex interaction of different management factors (Mitterer-Istyagin et al., 2011).

T3.7 Foot pad dermatitis (FPD)

Foot pad dermatitis (FPD) is a type of contact dermatitis affecting the plantar region of the feet (Wyneken et al., 2015). The skin of the foot pad becomes hard, scaly, necrotic and frequently splits (Mayne et al., 2007a; Sarica and Yamak, 2010). The resulting lesions can provide an entry point for bacteria which may then spread through the bloodstream and

compromise product quality (Abd El-Wahab et al., 2011). External signs of FPD are preceded by histopathological evidence of an inflammatory immune response, although poor associations have been found between external and histopathological foot pad scores (Mayne et al., 2007a). The inflammation resulting from FPD represents a potential source of pain and is a significant welfare concern for affected birds (Mayne et al., 2007a; Sarica and Yamak, 2010; Sinclair et al., 2015).

Prevalence of FPD can reach levels of 91-100% in commercial flocks and is gaining recognition as an indicator of well-being (Abd El-Wahab et al., 2011). The occurrence of FPD is used as part of welfare assessment audits of poultry production systems in Europe and the US (Abd El-Wahab et al., 2012b; Da Costa et al., 2014). A large survey of 60 tom turkey flocks in France examined the various lesions present on carcasses at 13 different abattoirs (Allain et al., 2013). All flocks had a high proportion of foot pad lesions, with 40.7% exhibiting severe FPD and 60% foot pad swelling, suggesting that foot lesions of all types should be monitored. However, as feet have no economic value and mobility does not tend to be impaired sufficiently to hinder feeding, FPD is often perceived only as an animal wellbeing concern rather than a production issue (Martrenchar et al., 2002), reducing the likelihood that action is taken to address this issue unless penalties from welfare audits are in place. However, unlike external foot pad scores, high pathological foot pad scores are associated with lower body weights, and therefore economic consequences, as well as providing some evidence of discomfort during locomotion (Mayne et al., 2007a).

The aetiology of FPD is a complex interaction of different factors (Abd El-Wahab et al., 2013a). Within commercial flocks, FPD originates in the early rearing phase (Bergmann et al., 2013). The prevalence and severity of foot pad alterations increases with age and sex differences have been found, with female poults at higher risk of developing these changes (Krautwald-Junghanns et al., 2011; Bergmann et al., 2013). High stocking densities in the first 3-5 days of rear have also been associated with an increased risk of foot pad alterations and as such even mild reductions in foot pad conditions can indicate that the rearing environment is suboptimal (Bergmann et al., 2013).

The integrity of the foot pad and walking ability are affected by several parameters present during the production cycles, most notably litter quality (Da Costa et al., 2014). High litter moisture content alone appears sufficient to cause FPD in young turkeys (Youssef et al., 2011b), although there is dispute over the threshold value (30% (Wu and Hocking, 2011); 35% (Abd El-Wahab et al., 2012a); 49% (Wyneken et al., 2015); maintaining dry litter is therefore a priority in the control of FPD (Mayne et al., 2007b; Wu and Hocking, 2011). No evidence has been found that litter pH (Wu and Hocking, 2011), or the presence of ammonia or uric acid (Youssef et al., 2011b) have a role in the pathogenesis of FPD. High macronutrient content of feed has only a marginal effect in comparison with the very strong influence of litter moisture (Youssef et al., 2011c). FPD can develop very rapidly in commercial flocks, with full foot pad lesions present after 48 hours of being exposed to wet litter (Mayne et al., 2007b). Females have a thinner epidermis than males and therefore appear to be at higher risk of developing FPD (Vermette et al., 2016). Factors that increase water excretion, for example intestinal infections such as coccidiosis (Abd El-Wahab et al., 2012b) and dietary concentrations of nutritional factors and electrolytes such as sodium and potassium (Youssef et al., 2011a; Abd El-Wahab et al., 2013a) can also predispose birds to FPD through their effect on the moisture content of the litter.

Floor heating has been found to reduce the severity of FPD, regardless of whether the litter is wet (35% moisture) or dry; however, it has been argued that if the birds are provided with well-balanced diets, proper stocking density and are in good health providing floor heating is not necessary (Abd El-Wahab et al., 2011). The type of litter used during different stages of the production cycle may also have an effect on FPD occurrence, possibly due to their differing capacities to absorb moisture (Mayne et al., 2007b). FPD was lower when lignocellulose (e.g. Soft Cell®) was used as a litter material in comparison to wood shavings (Abd El-Wahab et al., 2011). The cost involved in providing lignocellulose throughout the entire fattening period is prohibitive and consequently it is never likely to be used to this extent in practice, however, providing birds with lignocellulose in the rearing period may be sufficient to facilitate foot health for the subsequent fattening period littered on wood shavings (Abd El-Wahab et al., 2011). Whatever type of litter is used, it is clear that litter should be maintained as dry as possible to reduce the severity and prevalence of FPD in turkeys (Youssef et al., 2011b; 2012). As FPD is associated with higher feed intake but lower weight gains, the improvements seen in feed conversion efficiency when improving litter quality represents a potential saving that may offset the costs of taking action on FPD in commercial flocks (Hocking and Wu, 2013).

There is a positive correlation between FPD and the percentage of moisture in the air, meaning that there is a seasonal effect (Martrenchar et al., 2002). This correlation also demonstrates the important role the ventilation system plays in controlling the moisture content of the air, and consequently the moisture content of the litter and the likelihood of FPD occurring (Mayne et al., 2007b).

Turkeys with FPD show limited activity levels and behavioural repertoire, consistent with experiencing pain associated with the inflammatory response (Hocking and Wu, 2013; Sinclair et al., 2015; Dalton et al., 2016). Stance time is longer in turkeys on wet litter which may be interpreted as birds taking more care with their foot placement due to associated pain (Wyneken et al., 2015). FPD and gait score are positively correlated and increase with age; while this may be due to the corresponding increase in body weight (Da Costa et al., 2014), it could also be attributed to the pain associated with both conditions. It has been suggested that litter quality does not simply have a causative relationship with FPD. The finding

that birds have compromised welfare on wet litter alone, even without the presence of FPD, suggests that wet litter may induce a negative affective state in growing turkeys and if this is the case this may affect how pain is perceived, compounding the welfare implications of poor litter quality (Sinclair et al., 2015). This is an area that requires further research attention.

While it is possible to achieve low prevalence of FPD in chicken broilers under high commercial stocking densities, this does not appear to be the case for turkeys, which require greatly reduced stocking densities or improved floor drainage to control prevalence of FPD (Martrenchar et al., 2002). This suggests that under current production systems FPD is unlikely to be brought under control unless significant changes are made to the way turkeys are commercially farmed.

Substantial phenotypic variation in susceptibility to FPD exists (Wu and Hocking, 2011). The evidence for an inherited component of FPD suggests that genetic selection will be effective in reducing both the severity and the prevalence of FPD in turkey flocks (Hocking and Wu, 2013).

T3.8 Cellulitis/clostridial dermatitis (CD)

Cellulitis is a major meat hygiene and economic problem in the broiler industry primarily affecting adolescent and adult male turkeys (Gomis et al., 2002; Huff et al., 2013). Cellulitis is an inflammation of the skin and subcutaneous tissue, characterised by an accumulation of frothy sanguineous exudates under the skin of the breast and tail regions (Thachil et al., 2012). Lesions associated with cellulitis start appearing in affected turkeys around 7 weeks of age and may continue to 18 weeks or older (Thachil et al., 2012). Unlike in the broiler industry *Escherichia coli* is not the predominant infectious agent, rather *Clostridium* species, particularly *C. septicum* is thought to be the primary cause (Thachil et al., 2012; Huff et al., 2013). Prevalence and severity of cellulitis have increased since it was first reported in 1939, and mortality can now be as high as 1-2% in affected flocks (Thachil et al., 2012).

While there is no consensus on the risk factors and causes of CD, reducing drinker spillages and improving wet litter management have been identified as important for control (Huff et al., 2014). Huff et al. (2013) hypothesised that severe stress, such as the social and psychological stress induced by overcrowding, may undermine resistance to opportunistic pathogens like *C. septicum*, by increasing bacterial translocation from the gut and compromising the skin's antimicrobial barrier.

In half the cases examined in one study bacteria were not the causative agent at all, rather the unopened lesions observed were thought to be a form of contact dermatitis and consequently their aetiology is more likely to lie in poor management practices, for example wet litter, sharp objects and improper toe trimming (Gomis et al., 2002).

Cellulitis has traditionally been controlled preventatively by administering antimicrobials in feed and water, however the use of antimicrobials as a preventative strategy is increasingly criticised and the practice has been banned in some countries (Thachil et al., 2012).

T3.9 Eye abnormalities

Birds are highly sensitive to ammonia and exposure to high levels (50-100 µg/g) can result in blindness (Tran et al., 2015). Turkeys reared in constant or near constant lighting programs exhibit increased eye weights, enlarged eye size, corneal flattening and thinning of the retina and choroid (Vermette et al., 2016). Such eye abnormalities can greatly impede the birds' ability to perceive their surroundings, especially as the conditions progress, having significant welfare implications (Vermette et al., 2016).

T3.10 Parasitic infections

T3.10a Mites

Free-range turkeys in the USA may acquire bites from chiggers (*Neoschongastia* spp.) but mites do not appear to be a significant problem in indoor housed turkey flocks. A survey of the arthropod fauna present in the litter in commercial turkey farms in the US identified mites belonging to two orders and nine families in the growing shed litter and the litter in the brooder shed, but these were not commercially-relevant ectoparasites (Rueda and Axtell, 1997).

T3.10b Coccidiosis

Clinical signs of coccidiosis in turkeys are not disease specific (pathognomonic) and include appetite loss, listlessness, huddling, diarrhoea, drooping wings and ruffled feathers (Abd El-Wahab et al., 2012b). Watery excreta is one of the most important signs characterising coccidial infection (Abd El-Wahab et al., 2012b). The process of sporulation appears to be affected by the moisture content and temperature of the litter (Abd El-Wahab et al., 2013b). Increased litter moisture resulting from coccidial infection also acts as a risk factor for other diseases such as FPD. Pressure to replace the use of anti-coccidial drugs means that many commercial turkeys are now vaccinated at day old (see also LH3.11b and B3.5b).

T3.10c Worms

Turkeys are susceptible to helminth infections. The nematode *Heterakis gallinarum* occurred at a prevalence of 70% in Brazilian flocks and infection was associated with chronic inflammatory processes in the ceca detected by histological examination (Brener et al., 2006).

T3.10d Protozoa

The protozoan *Histomonas meleagridis*, is the cause of enterohepatitis or blackhead in turkeys. It causes severe liver and caecal lesions in infected birds. Contaminated eggs of *Heterakis gallinarum* act as a vector, hence the two pathogens are found in association (Brener et al., 2006).

T3.11 Infectious diseases

T3.11a Turkey reoviruses (TRV)

Turkey reoviruses (TRV) can cause arthritis, tenosynovitis and enteric diseases in turkeys, resulting in large economic losses (Mor et al., 2015). In a laboratory study, Mor et al. (2015) found that TRVs were able to survive 9-12 weeks in autoclaved water and 5-7 weeks in autoclaved litter. However, in commercial conditions infected birds will shed virus continuously and the virus may therefore survive the whole life cycle of the flock (Mor et al., 2015).

T3.11b Poult enteritis mortality syndrome (PEMS)

Poult Enteritis Mortality Syndrome (PEMS) is a clinical syndrome characterised by excess (mortality greater than 2% for any 3 week period during the brooding phase of production) and spiking (mortality greater than 9% for any 3 week period during the brooding phase of production) mortality and is positively associated with turkey coronavirus (Carver et al., 2002b). PEMS had a significant impact on turkey farming in North Carolina, USA, during the 1990s (Carver et al., 2002b). A negative association has been found between PEMS and enhanced rodent control practices with a 10-fold reduction in disease risk if enhanced control practices were in place (Carver et al., 2002b). As this study was based on observational data, causality could not be determined, so it is unknown whether rodents carry PEMS or whether enhanced rodent control is a proxy for other improved management practices (Carver et al., 2002b). Empirical studies are required to investigate this relationship further.

T4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

Unlike domestic chickens, the behavioural needs of domestic turkeys have received very little research attention. The evidence that does exist suggests that like their chicken counterparts, domestic turkeys require the ability to nest, perch, dust-bathe and forage; however the strength of their motivation to perform these behaviours is currently untested.

T4.1 Behavioural need for a nest

Wild turkey hens build nests on which to incubate and raise their chicks.

An experimental study comparing incubation behaviour and hormonal parameters in turkey hens exposed to different rearing environments (battery cage without a nest box, individual floor pens with a nestbox and group floor pens with nestboxes), found that environment had a significant influence on both hormones and incubation behaviour (Bédécarrats et al., 1997). The hens housed in the group pens expressed higher levels of incubation behaviour, higher prolactin levels and laid more eggs in their nestboxes and the authors hypothesised that the greater visual and tactile exposure to eggs and nestboxes may have facilitated this difference (Bédécarrats et al., 1997). Empirical evidence on turkeys' need for a nest appears to be lacking. However, given that wild turkey hens place considerable importance on nest site and that experimental studies have demonstrated that turkey hens will use nest boxes if they are provided, this would indicate that turkey breeder hens should have access to some form of nest.

T4.2 Behavioural need to perch

Turkeys are known to roost in the wild (Bessei, 1999, cited by Martrenchar et al., 2001), yet domestic turkeys are not typically provided with any means of performing this behaviour in a commercial setting (Martrenchar et al., 2001). However, when perches are provided, the use of elevated levels as a perching place was significantly higher in the dark periods (Berk and Hahn, 2000) suggesting that commercial turkeys will use perches or elevated levels to roost.

Use of perches and elevated structures by fattening turkeys varies with age, stocking density, light period and the genetic line of the turkey (Berk and Hahn, 2000). However, a higher incidence of hygroma and breast blisters in birds using perches suggests that the compression of this area when perching can negatively impact on bird health, especially in heavy birds (Berk and Hahn, 2000). Consequently, the use of elevated levels rather than perches *per se* may be more appropriate for fattening turkeys (Berk and Hahn, 2000).

Perching activity peaks around 5-7 weeks of age, after which use decreases, most likely due to the increased weight of the birds impacting their mobility (Berk and Hahn, 2000). While a reduction in motivation to perch as age increases cannot be discounted (Martrenchar et al., 2001), evidence that older birds will still climb on to straw bales or use wider, lower perches suggests that the motivation persists with age (Sainsbury and Sherwin, 2001). It seems to be the physical constraints imposed by the heavy weight of modern strains that restricts the use of perches in commercial turkeys (Bessei, 1999, cited by Martrenchar et al., 2001).

T4.3 Behavioural need to forage

In commercial systems, the investigative and foraging behaviour of turkeys appears to be almost entirely beak based, rather than the ground scratching observed in other poultry species and in wild turkeys (Hughes and Grigor, 1996). Although environmental pecking reportedly decreases with age (Sherwin and Kelland, 1998), foraging does appear to be a highly motivated behaviour. Indeed, turkeys given access to a pasture on which to forage spend most of their time grazing (Karabayir et al., 2008). Lack of foraging opportunities in commercial systems has been associated with the performance of injurious pecking (Dalton et al., 2013).

One thing that should be noted is that the restrictions imposed by the physical conformation of modern turkey strains has greatly changed their daily time budgets in comparison to lighter strains and their wild counterparts. Only light strains are able to respond to the opportunities provided by free range systems and increase their locomotion and foraging activities (Bessei, 1999, cited by Martrenchar et al., 2001).

T4.4 Behavioural need to dust-bathe

When provided with appropriate conditions, for example, fresh shavings, domestic turkeys will engage in dust-bathing (Sherwin and Kelland, 1998) and this behaviour appears to be socially facilitated (Sainsbury and Sherwin, 2001). It is likely that turkeys are unable to perform this behaviour in typical commercial systems due to the formation of a non-friable crust on the litter. The strength of motivation to perform this behaviour in farmed turkeys has yet to be investigated.

T4.5 Social behaviour

Turkeys are highly social birds. In experimental studies turkeys have been found to discriminate against unfamiliar birds, spending more time in close proximity to familiar group members and showing increased aggressive interactions towards unfamiliar birds (Buchwalder and Huber-Eicher, 2003; 2005a). Data on the number of individuals that turkeys are capable of recognising is limited, but observations of wild turkeys fighting as groups of 2-20 individuals indicated that non-group members were recognised and rejected (Watts and Stokes, 1971; Williams, 1981; both cited by Buchwalder and Huber-Eicher, 2003). Experimentally, turkeys housed in large groups of 30 showed significantly less aggression to a newly introduced unfamiliar individual than turkeys housed in small groups of 6, suggesting that in larger groups the turkeys are unable to distinguish between familiar and unfamiliar individuals (Buchwalder and Huber-Eicher, 2005a). This would imply that distinction between conspecifics is based on individual recognition rather than uniform group characteristics that allow birds to identify group and non-group members (Buchwalder and Huber-Eicher, 2005a). The smaller groups of 6 birds established a stable dominance hierarchy based on individual recognition and therefore reacted more aggressively to the introduction of an unfamiliar individual (Buchwalder and Huber-Eicher, 2005a).

The distance at which a turkey is no longer able to discriminate conspecifics has been used to explain the relationship between stocking density and aggressive behaviour; birds that are able to retreat a sufficient distance are no longer targeted by the aggressor, hypothetically because they can no longer be individually recognised at this distance (Buchwalder and Huber-Eicher, 2004). This hypothesis has yet to be substantiated experimentally.

Under commercial conditions turkeys live in much larger group sizes than their ancestors and it is likely that the increased aggression seen in commercial systems reflects attempts by the birds to establish stable dominance hierarchies within a group that is too large for successful individual recognition (Buchwalder and Huber-Eicher, 2005a).

T5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

The type of turkey rearing system used has limited impact on behavioural usage as the behaviour of commercial birds is so fundamentally compromised by their fast growth and conformation that they are unable to take full advantage of perches, ranges or other facilities offered. The most critical feature of commercial turkey facilities is litter quality which has a significant impact on the aetiology and severity of painful pathological conditions.

It has been suggested that the behavioural needs of turkeys cannot be fulfilled while the heavy broad breasted strains are so significantly limited by their conformation (Hirt, 1998, cited by Berk and Hahn, 2000). No continuous influence of housing system on the physical and chemical composition of breast and thigh meat was observed when the carcasses of birds with access to perches, free range or neither of these facilities were compared (Berk and Hahn, 2000), possibly because the strains compared were unable to make full use of the features offered in the different systems.

T5.1 Indoor systems

Turkeys are typically reared commercially in either fully enclosed or curtain-sided/pole barns (Duggan et al., 2014). Fully enclosed barns enable greater control over the birds' environment, while curtain-sided barns allow the birds some exposure to outdoor conditions and natural sunlight (Duggan et al., 2014). Curtain-sided barns have been associated with higher levels of cull and mortality rates and worse feather condition than levels seen in fully enclosed barns (Duggan et al., 2014). It should be remembered that the turkey industry has a seasonal component, with some producers only raising turkeys at certain times of year. Turkeys raised for the seasonal market are more frequently housed in pole barns. This is likely to have an impact on the welfare of turkeys in these transient systems as they may lack the investment, for example in ventilation systems, seen in turkey systems used for continuous production and there is a lack of environmental control. This issue does not appear to have received research attention to date.

T5.1a Litter

The quality of the litter in indoor housing systems can greatly impact on the health and welfare of turkeys (Slobodzian-Ksenicz et al., 2010; Abd El-Wahab et al., 2011) and poor quality litter can greatly impede the birds' ability to perform to their genetic potential (Tran et al., 2015).

The impact of litter quality on foot pad health is significant since foot pads are in constant contact with the litter throughout the production cycle (Tran et al., 2015). Turkeys with impaired mobility spend more time sitting, increasing their litter contact time and consequently their risk of skin lesions like breast blisters (Vermette et al., 2016). As previously discussed in section T3.7 the moisture content of the litter has particular relevance when it comes to foot health. Even without the added negative implications of FPD, there is evidence that wet litter alone can reduce the welfare of growing turkeys (Sinclair et al., 2015). This finding suggests that wet litter and pain from FPD are confounding factors and this should be considered in future studies (Sinclair et al., 2015).

Litter moisture can be affected by a number of factors, including, but not limited to, stocking density, ventilation and drinker design (Abd El-Wahab et al., 2012b), the physical properties of the bedding material including its capacity for water retention, seasonality and nutritional parameters that affect the consistency of excreta (Farahat et al., 2013b; Da Costa et al., 2014). Diarrhoea, for example due to coccidiosis infection, is one of the leading causes of wet litter (Abd El-Wahab et al., 2012b). The critical litter moisture content for the development of FPD lesions is about 35% (Abd El-Wahab et al., 2012a).

In temperate climates wood shavings and cereal straw are commonly provided as litter, rice hulls are often used in tropical climates (Mayne et al., 2007b). Alternate litter materials made from recycled or waste materials from other industries, for example newspaper, cardboard (Mayne et al., 2007b) and dairy waste may also be used (Frame et al., 2004). Pelletised newspaper was associated with greater moisture absorbency, fewer foot pad abnormalities, lower fungal count, and lower litter associated mortality (thought to be due to birds more easily distinguishing between the dark coloured pellets and light coloured food) in one study (Frame et al., 2002). In contrast composted dairy waste was associated with more foot pad problems by 35 days of age, although there were no subsequent significant differences in mortality or walking ability compared with turkeys kept on pine wood shavings litter for the first 35 days (Frame et al., 2004).

Behavioural differences have been observed between turkeys on wet and dry litter, with the poults on wet litter spending a very high proportion of the time sleeping or preening while standing, while birds on dry litter spent more time walking and sitting, the lack of activity on wet litter perhaps reflecting a response to pain arising from inflamed foot pads (Hocking and Wu, 2013). Poults on dry litter exhibited a greater range and complexity of behaviour while the limited range of behaviour seen by the poults on wet litter is similar to the behavioural disruption seen when exposed to stressful situations such as food restriction and disease (Hocking and Wu, 2013). Poults on wet litter also show increased feed intake but lower weight gain, combined with less active behaviour, suggesting that the increased feed intake is not sufficient to compensate for the energy lost maintaining body temperature and mounting an inflammatory response (Hocking and Wu, 2013). Consequently, keeping poults on wet litter not only compromises bird health and welfare but reduces feed conversion efficiency thereby raising production costs (Hocking and Wu, 2013).

Commercial turkeys have a longer period of rearing than commercial chicken broilers (Martrenchar et al., 2002), consequently remaining in contact with suboptimal environmental features like wet litter for a longer duration, therefore litter management has a great bearing on the welfare of turkeys. Although sheds are not cleaned out during the production cycle, or even between production cycles in some cases (Thachil et al., 2012), many farmers add extra litter material. The added depth of litter may retain moisture while a thinner litter layer may be easier to keep dry and maintain, although may provide challenges to meet the thermal requirements of young poults early in production (Martrenchar et al., 2002). Handling and disposing of used litter is becoming increasingly challenging and it has reportedly resulted in many turkey producers reusing litter for more than a year of production (Tran et al., 2015), increasing disease risk. The microbiological load of litter builds up over time and is increased in poor quality litter, exposing birds to health challenges from parasites such as coccidian, other protozoa, fungi, enteric viruses and environmental bacteria (Ritz et al., 2009, cited by Tran et al., 2015).

Additives can be used to improve the quality of the litter and the microclimate of the growing shed, and in doing so the health and welfare status of the turkeys (Slobodzian-Ksenicz et al., 2008). The addition of brown coal lowered the air concentration of carbon dioxide and ammonia as well as the relative air and litter humidity in the shed, delayed the development of a crust on the surface of the litter and was associated with lower mortality and higher final weight (Slobodzian-Ksenicz et al., 2008). Similar positive effects have been found with the addition of cellulose (Slobodzian-Ksenicz et al., 2010).

Poor litter quality is the primary cause of ammonia volatilisation which can have a significant impact on air quality (Tran et al., 2015). There is a correlation between NH_4^+ concentrations in litter and the efficiency of feed conversion (Tran et al., 2015).

T5.2 Free-range systems

Fattening turkeys do make use of access to free range, but this use is limited as their age and body weight increases and their locomotion becomes impaired (Berk and Hahn, 2000).

There is also evidence that welfare in free range systems may face additional challenges to those faced by indoor housed birds. In comparison to turkeys reared in a commercial and an experimental setup, turkeys reared in a backyard system were found to have compromised immune parameters, perhaps reflecting the stress imposed by exposure to temperature fluctuations and predators (Franciosi et al., 2011). However, it should be noted that this study used a strain of turkeys genetically selected for and adapted to commercial production in indoor rearing systems and this may not be the case if more traditional strains are used in outdoor systems.

In free-range systems, environmental conditions play an important role in determining the wetness of the litter, and therefore the occurrence of FPD (Sarica and Yamak, 2010).

T6. FEAR AND DISTRESS

Fear and distress have received relatively little focused research attention in domestic turkeys in comparison to other farmed poultry species. However, there is no evidence to suggest that turkeys are in any way less likely to experience these negative states than other poultry species.

T6.1 Stress

Measures of physiological stress used in chickens, such as plasma corticosterone and H:L ratio are also used in turkeys, e.g. to assess responses to procedures such as toe trimming, beak trimming and desnooding conducted in the hatchery (see T8.2) (Donaldson et al., 1991; 1994). Turkeys also show increases in plasma creatine kinase activity in response to stress. Plasma creatine kinase is generally a useful indicator of muscle damage and it was thought that it might be a useful measure of leg weakness. However, high values of plasma creatine kinase may persist for at least 29 hours post stressor, limiting its usefulness for other purposes unless stress can be controlled (Reece et al., 2000).

Unfavourable microclimatic conditions (high temperature (31-35 °C), high humidity (55-57%), high ammoniac concentrations (20 µg/l) and weak light intensity (21-23 lux) have been used to create experimentally induced environmental stress in turkeys (Stoyanchev, 2007). These environmental stressors were shown to exacerbate symptoms of weakness and paralysis in turkeys that had pre-existing signs of muscular dystrophy (Stoyanchev, 2007).

Diuresis (the production of increased urine) is a normal reaction to stress in birds and turkeys are no exception (Huff et al., 2014). The consequences of this stress response are reduced litter quality due to increased litter moisture and therefore an increased risk of FPD and CD.

T6.2 Fear

There has been very little research describing or characterising fear responses in turkeys (Erasmus and Swanson, 2014). Feather raising is one possible fear response (Ellerbrock and Knierim, 2002). Turkeys also exhibit tonic immobility in response to fear/stress, for example flock disruption and handling (Vermette et al., 2016). One experimental study found a high level of individual variation in fear responses between birds, with some displaying little or no reaction during testing while others became extremely active and vocal (Erasmus and Swanson, 2014). Responses to fear tests such as open field, novel object, voluntary approach and tonic immobility tests have been used as part of welfare assessments in other poultry species, however such tests have yet to be validated in turkeys. Evidence suggests that the responses of turkeys to open field, tonic immobility and voluntary approach tests are repeatable over time, while responses to novel object tests appeared more variable, indicating that only three of the four tests may have a place in turkey welfare assessments (Erasmus and Swanson, 2014).

T7. SENSORY ENVIRONMENT

T7.1 Light and vision

The lighting quality and regime imposed on farmed turkeys has been researched more than other aspect of the birds' sensory environment, probably due to the relationship between light levels and the occurrence of injurious pecking. Turkeys are typically produced at very low light levels in an attempt to control this behaviour which has negative implications for their vision and eye morphology.

Commercial turkey poult houses are typically maintained at a much lower illuminance than daylight and the spectral powers distributions of the light sources, and colour balance, are of a different quality (Barber et al., 2004), for example they include minimal UV, suggesting that these artificial light sources may be unsuited to the visual ecology of turkeys (Moinard and Sherwin, 1999).

A survey of 16 turkey poult houses in the UK found that none of them admitted daylight to their houses; instead the majority used an incandescent, as opposed to fluorescent, light source and did not have a dawn/dusk lighting system in place (Barber et al., 2004).

Turkey poults show a preference for different light environments at different ages and for different behaviours (Barber et al., 2004). While 2 week old poults significantly prefer environments of 200 lux, at 6 weeks they prefer illuminances greater than 6 lux for inactive behaviour such as resting and perching and illuminances greater than 20 lux for other activities (Barber et al., 2004). However, commercial units rarely use such high illuminances because of the increased risk of injurious pecking (Barber et al., 2004). Instead the light levels in some turkey houses may be below 1 lux. Such a poorly illuminated environment is highly unnatural and can lead to changes in eye morphology, often severe enough to result in partial or total blindness (Buchwalder and Huber-Eicher, 2004).

Given the diurnal nature of turkeys, it may be appropriate to assume that they possess a cone-based retina similar to that of other diurnal birds (Barber et al., 2004) and there is evidence to suggest that turkeys are sensitive to ultraviolet (UV) radiation (Hart et al., 1999, cited by Lewis et al., 2000). The limited UV radiation in artificially illuminated poultry houses is likely to impair the ability of turkeys to use their UV sensitivity for foraging, and for forming and maintaining social hierarchies (Lewis et al., 2000). In experimental conditions, providing UV radiation throughout the whole growing period prevented injurious pecking in intact (untouched toes, beaks and snoods) male turkeys during the period of sexual maturation, and the benefits are increased if environmental enrichment (straw) is also provided (Lewis et al., 2000).

Day length can influence behaviour, the incidence of skeletal abnormalities, mobility, growth and eye health, and so ultimately the welfare of domestic birds (Vermette et al., 2016). Day length still has an impact, even when lighting programs are maintained at low light intensities (2 lux) (Vermette et al., 2016). Day length has a more pronounced effect on the welfare of toms than hens, but linear effects on mobility, breast blisters and altered eye size were noted for both toms and hens in one study that considered daylengths of 14 to 23h (Vermette et al., 2016). Behaviour was only measured in toms, but the reduction in active behaviours and increase in resting suggests that the toms were experiencing lethargy and a lack of ability or motivation to perform some behaviours with increasing day length (Vermette et al., 2016).

Sexual maturity in turkeys reared for egg production is stimulated by extending the photoperiod from under 8 hours to over 12 hours of light, with the onset of sexual maturity occurring 14 days after the change in photoperiod (Bédécarrats et al., 1997).

T7.2 Sound, noise and hearing

Wild turkeys are highly vocal and perform a wide repertoire of calls (Sainsbury and Sherwin, 2001). Some domestic turkeys become extremely vocal during fear tests (Erasmus and Swanson, 2014), indicating that the use of vocalisations has not diminished in domestic birds. That said, the acoustic abilities of turkeys and the impact of sound on turkey welfare lack research attention.

T7.3 Thermal comfort

Heat stress is a potential problem for turkeys, particularly at high stocking densities where behavioural cooling strategies may be restricted.

With the improvements seen in growth performance, feed conversion and livability of fast growing meat turkeys in recent decades, has been a corresponding increase in metabolic rate and therefore in heat production, and with it the additional challenge for the turkeys of coping with extreme environmental conditions (Yahav et al., 2008; Mendes et al., 2013).

Turkey poults are susceptible to heat stress, particularly the heavy fast-growing males (Jankowski et al., 2015) and heat stress is a major welfare problem in the poultry industry (Konca, et al., 2008). It has been suggested that turkeys are less

sensitive to heat stress than other poult species due to their ability to dissipate heat from their wattles (Yahav, 1998; 1999, both cited by Konca et al., 2008).

Turkeys use compound ventilation, a combination of breathing and panting (Brown-Brandl et al., 1997, cited by Yahav et al., 2000), to cope with high ambient temperature and relative humidity, and they have more efficient renal bicarbonate compensation than chickens, meaning they are more resistant to changes in their blood acid-base (Yahav, 2000). Behaviourally, turkeys cope with high ambient temperatures by reducing feed intake, increasing water intake and excretion, spreading and dropping wings to expose unfeathered areas, reducing physical activity and increasing panting (Veldkamp et al., 2002).

Ventilation system also has an impact on the thermal comfort of indoor housed turkeys. Inadequate ventilation of humid air can increase ammonia levels and the moisture content of the litter, leading to elevated prevalence of FPD (Martrenchar et al., 2002; Dalton et al., 2016).

In a comparison of positive and negative pressure ventilation systems, no influence on carbon dioxide levels was found, although the positive pressure system provided less aversive temperature and humidity conditions as well as improving feed conversion (Mendes et al., 2013).

Air velocity plays an important role in the performance and thermoregulation of young turkeys (Yahav et al., 2008). Ambient temperature of 30 °C coupled with air velocity from 1.5-2.5 m/s represents an optimal combination of conditions for young turkey performance in experimental conditions (Yahav et al., 2008).

T8. MANAGEMENT AND HANDLING

T8.1 Stocking density and group size

High stocking density is strongly associated with increased aggression, reduced litter quality and an increased risk of heat stress (T6.1) and foot pad dermatitis (T3.7).

Stocking density of growing poults changes with age and higher densities can adversely affect growth rate and mortality (Berk and Hahn, 2000) and lead to the accumulation of heat in sheds increasing the risk of heat stress and hyperthermia (Jankowski et al., 2015). These environmental factors negatively impact the skeletal properties of poults through a combination of decreased activity, corticosterone over-secretion and reduced food intake (Jankowski et al., 2015).

Stocking densities are typically based on static space requirements; however consideration should also be given to the birds' behavioural and social space requirements (Ellerbrock and Knierim, 2002). The calculation of space requirements becomes more complex once behavioural and social space requirements are taken into consideration. Older, heavier male turkeys are likely to require more social space than younger birds as they become increasingly aggressive with age; they may also need increased space for behavioural thermoregulation and to dissipate heat in high ambient temperatures (Ellerbrock and Knierim, 2002). However, these older, heavier birds are likely to have a reduced range of movement as their weight and associated factors impacts on their mobility and consequently they may be seen to have lower behavioural space requirements than younger, more mobile birds (Ellerbrock and Knierim, 2002). In contrast to chicken broilers, a reduction in the stocking density of meat turkeys did not result in an increase in activity (Martrenchar et al., 1999), most likely due to the constraints of the birds' physical conformation.

One hypothesis for the elevated levels of aggression observed in commercial flocks is that individuals do not have the space available to retreat from aggressive encounters (Buchwalder and Huber-Eicher, 2004). This has been explored in experimental situations which suggested a stocking rate much lower than the common level of 3 birds/m² was required before the birds had sufficient distance to retreat, however the maximal stocking rate at which birds are still able to retreat sufficiently to avoid aggressive encounters has yet to be studied (Buchwalder and Huber-Eicher, 2004).

As stocking density increases there appears to be more disturbance to resting birds, as they are trampled over by others (Martrenchar et al., 1999). This disruption of the birds' resting or sleep cycles, in conjunction with the increased injury risk during trampling is likely to have implications for the welfare of densely stocked turkeys.

T8.2 Procedures

Prior to moving from commercial hatcheries, turkey poults undergo a number of procedures before being placed in rearing facilities. The poults are sexed, and then depending on the requirements of the rearing facility, they have their beaks and toes trimmed, their snood removed (males only) and are injected with nutrients and/or medications before being held without food or water prior to placement. The combined effect of these procedures is stressful (Donaldson et al., 1991; 1994) and there is likely to be significant pain associated with beak trimming, toe trimming and snood removal.

T8.2a Beak trimming

Turkeys are beak trimmed to control feather pecking and cannibalism (Busayi et al., 2006). This procedure is typically conducted with infra-red lasers on day old poults (Dalton et al., 2013) in a process similar to that used for chickens. It has been suggested that beak trimming itself may lead to the development of feather pecking as the birds become frustrated over their impaired ability to grasp feathers and become highly motivated to continue the behaviour until the pecking and pulling action is complete (Dalton et al., 2013). As in chickens, there is also the risk that beak trimming will lead to the development of chronic pain in beak trimmed birds.

T8.2b Toe trimming

Turkey carcasses can be downgraded if their quality is impaired. Toe trimming, whereby the claws on the 3 anterior facing digits on both feet are removed, historically using surgical shears or hot-blade cauterising, or more recently by a microwave claw processor (MCP), is the industry's response to the risk of downgrades from scratching (Fournier et al., 2014). A MCP is an automated system whereby the tips of the toes to be trimmed are exposed to microwave, killing the tissue which then falls off 1-3 weeks post exposure (Fournier et al., 2015). It has been suggested that (for broilers) the pain caused by toe-trimming early in life may be outweighed by the chronic pain the birds would have endured later in life from lacerations and subsequent infections that would have resulted from the toes and claws of the other birds if these had not been removed (Wang et al., 2008). However, no evidence on the prevalence of such lacerations was presented to support this opinion.

There is evidence of reduced welfare in heavy toms following toe trimming by MCP, with behavioural indicators of short term pain, including an increase in resting and sitting and reduction in feeding behaviour, in the 5 days immediately after the procedure (Fournier et al., 2015). In the longer term (133 days post-procedure), there was behavioural evidence that while the trimmed birds did not appear to be in pain they were more reluctant to walk perhaps due to instability resulting from the removed toe tissue impairing their balance (Fournier et al., 2015). Research on heavy toms suggests that feed consumption and consequently body weight, and the incidence of rotated tibiae can be negatively affected by MCP toe trimming, while no positive effect on carcass scratches was detected (Fournier et al., 2014). In light of these combined findings, the expense and negative welfare impact of trimming does not appear to be compensated by improved productivity and carcass quality (Fournier et al., 2014). It is unknown whether these findings can be generalised outside of heavy tom production.

T8.2c Snood trimming/desnooding males

The snood or frontal process is a fleshy, highly vascularised and innervated appendage located caudal to the nares in male birds (Morishita, 1999). Snoods and spurs are male turkeys' secondary sexual ornamentation (Dalton et al., 2016). Commercial turkeys have been bred for reduced spurs (Dalton et al., 2016), however, snood size has not been reduced sufficiently to remain intact in a commercial setting and snoods are often removed to prevent damage to the snood from other birds. Trauma to the snood has also been associated with certain diseases such as erysipelas, and snood removal is recommended as a preventative measure (Morishita, 1999). Removal of the snood is known as desnooding and is conducted by clipping or pinching off the snood from day old poults (Morishita 1999). If desnooding is done incorrectly it can lead to chronic pain (Freeman, 1987, cited by Dalton et al., 2013).

In wild male turkeys snood length is negatively correlated with coccidia parasite burden and positively correlated with body condition and age (Buchholz, 1997). As a longer relaxed snood length is predictive of a victorious outcome in male-male interactions it is likely that males use these features to assess the risks of entering into combat with another male (Buchholz, 1997). These structures develop once the bird reaches sexual maturity and their size is likely to be testosterone dependent (Buchholz, 1997). It is likely that an absence of snoods may impair the judgement call of turkeys entering into aggressive combat. Although Dalton et al. (2016) found no correlation between snood length and head and neck injuries from aggressive encounters in their study.

T8.2d Artificial reproduction

Due to the large breast size of the modern male turkey, which makes natural breeding difficult, turkeys are predominantly bred using artificial insemination (AI) (Morishita, 1999). AI is also considered beneficial to the welfare of the hen who may otherwise be damaged during mating attempts (Sainsbury and Sherwin, 2001), although saddles have been used to protect hens from the tom's claws during mating outside of commercial settings.

The implications of AI for the welfare of the birds concerned does not appear to have been investigated experimentally in turkeys, the principle focus of any research conducted being procedural refinements. The collection of the semen from the toms and the insemination of the hen are likely to be aversive to both parties and warrant scientific investigation from a welfare perspective.

T8.2e General handling and inspection

Marchewka et al. (2015) suggest that turkeys could be inspected efficiently by two observers walking transects, and recording the total number of birds that are immobile, lame, aggressive towards a mate, interacting with humans, with visible head, vent, or back wounds, engaged in mounting behaviours, small in size, featherless, dirty, sick, moribund or dead. It has also been suggested that monitoring wattle temperature using an infra-red digital thermometer could provide a useful noninvasive tool for assessing turkey welfare when environmental conditions become challenging (Mendes et al., 2015).

As for broilers, there is evidence that automated catching can reduce damage to turkeys and that it is a less stressful procedure than manual catching (Prescott et al., 2000).

T9. WELFARE CONSIDERATIONS: OVERVIEW

Turkeys have been the subject of intense selection pressure. Rapid growth rates, disproportionate accumulation of breast tissue and heavy ultimate slaughter weights can lead to musculoskeletal problems and a range of developmental disorders. These can greatly reduce turkey welfare due to associated lameness, pain, increased susceptibility to fracture, inactivity and compromised behaviour.

The use of strains with lower growth rates and improved musculoskeletal health outcomes will help to ensure good welfare. In addition, diets that ensure healthy, but not excessive growth rates should be provided. Due to ongoing selection for growth traits, breed requirements for calcium, phosphorus and micronutrient intake can change over time, and producers should ensure that they use diets formulated for their current strain of bird.

Identifying the differential causes of injurious pecking in turkeys is an area of research that has not received sufficient attention. Compared with laying hens, there is a weaker evidence base from which to devise effective management strategies to reduce inter-bird pecking. Presenting food in mash rather than pellet form, and providing high fibre pecking substrates has some beneficial effects. Turkeys are often kept under very low light levels in an attempt to reduce injurious pecking but this may have other adverse welfare consequences. Further research on methods of preventing injurious pecking in turkeys is needed.

Aggressive interactions pose a greater threat to welfare in turkeys than most other farmed bird species. The turkey is a highly social bird, but can be aggressive in establishing dominance relationships and in competing for resources. High stocking densities can increase levels of aggression as birds are unable to move away from aggressors.

Foot pad dermatitis (FPD) occurs at a very high prevalence rate in many commercial turkey flocks. The primary risk factor is wet litter, and all steps should be taken to maintain a litter substrate with a moisture content of less than approximately 30-35%. Factors that assist in maintaining a dry litter substrate include lower stocking density, effective ventilation systems, the use of highly absorbent litter materials and (under certain cold or wet climatic conditions) measures such as floor drainage or underfloor heating. Regular assessment of the prevalence of FPD is assessed regularly at the slaughterhouse and the setting of targets for a progressive reduction in this condition will help to address FPD.

Dermatitis of other skin regions, notably the breast and the hock, is similarly associated with inflammation and an increased risk of infectious cellulitis. As for FPD, reducing litter moisture is key to reducing the prevalence and severity of these conditions.

The provision of low-level perches or elevated platforms should be considered as a means of satisfying roosting motivation, particularly in younger birds.

Turkeys are often housed under near-continuous, but very low light intensity, lighting programmes. This can have adverse effects on eye health, lameness and FPD because such lighting regimes are designed to encourage bird inactivity. Eye problems, active behavioural repertoire, leg and skin health can all be improved by longer continuous dark periods (up to 10 h dark). Light intensities should be sufficient to enable good flock inspection and avoid eye problems.

High stocking densities contribute to welfare problems including aggression, FPD, heat stress and reduced air quality.

Toe trimming causes pain and has no beneficial effect in reducing lacerations or carcase quality in growing turkeys. The potential beneficial effects of toe trimming for breeding turkeys (e.g. reduced injury to breeding females) have not been quantified and so it is not possible to assess whether harm is outweighed by benefit.

Information on the welfare consequences of snood removal in turkeys is lacking, along with any quantitative assessment of its potential benefits. This is an area that would benefit from future research.

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GUINEA FOWL

GF1. INTRODUCTION

GF1.1 Life history

Guineafowl are Galliform birds endemic to the African continent, and comprise four different genera: *Numida*, *Agelastes*, *Guttera* and *Acryllium*. It is likely that modern semi-domesticated guineafowl are derived from a West African subspecies of helmeted guineafowl (*Numida meleagris galatea*). Guineafowl thrive in fragmented habitats (Ratcliffe and Crowe, 2001) and are commonly found in savannah habitats that are mixed with cultivated areas, with the savannahs providing roosts, nesting cover and refuge, while cultivated land provides food (Malan and Benn, 1999). Home ranges observed by Njiforti and Kortekaas (1998) varied between 3.1-3.6 km².

Guineafowl, like chickens, are primarily ground living, although they can fly short distances. They are omnivores, foraging for food by pecking and scratching at the ground and their diet is varied, including grains, crop residues, corms, tubers, seeds, green leaves, and invertebrates (Prinsloo et al., 2008). Guineafowl nest on the ground in scrapes, but roost at night in low branches.

Elbin et al. (1986) studied the social behaviour of wild helmeted guineafowl. Birds formed mixed-sex flocks of 20-30 birds outside of the breeding season, and roosted communally at all times, except during incubation and brooding. During the breeding season males associated sequentially with one or more females, with one stable male-female pair forming after four to six weeks, and remaining together throughout the breeding season, maintained by vocalisation and posturing. Males also fed their mates during courtship and guarded them during egg laying and incubation.

Guineafowl lay 15-20 eggs per clutch (Ayeni, 1980, cited by Njiforti, 1997), and breed just once a year. Females incubated the eggs for approximately 30 days, and both males and females brooded the chicks for 12 days after hatch, and led the keets (chicks) during foraging (Elbin et al., 1986).

Males may be aggressive during the breeding season, defending their mates. If they detect an intruder mated males will approach the intruder in a hunchback posture and then retreat. If the intruder does not retreat the mated male will pursue and may physically attack the intruder (Elbin et al., 1986).

Guinea fowl are unlikely to have been subject to the same level of domestication as chickens, and tend to be slightly smaller and flightier. Despite this, their close phylogenetic relationship and similar ecological niche means that it is likely that the two species will have similar behavioural needs, and concomitantly similar welfare concerns. The only specific information identified relates to stocking density/group size for farmed guinea fowl.

GF2. MANAGEMENT AND HANDLING

GF2.1 Stocking density and group size

Stocking density and group size are associated with mortality and production. Mortality is higher and production parameters are lower at higher stocking densities in both cage and floor pen systems.

Stocking density, mediated by group size, has been associated with mortality and production in Pearl Grey Guinea fowl, both in cage systems and floor rearing systems. Nahashon et al. (2006) compared birds housed in cages at three stocking densities and group sizes: 465, 697, 1,394 cm²/bird (or 3, 2 or 1 birds/cage, respectively). They found that by 72 weeks of age cumulative mortality was lowest in the lowest stocking density/group size condition, and highest in the highest stocking density/group size condition. Feed conversion ratio was lower, while egg production, egg mass and body weight were all higher in the lowest stocking density/group size condition. Nahashon et al. (2011) reared pullets in floor pens from day-old to 16 weeks of age at three stocking densities/group sizes: 18, 15.6, 13.6 and 12 birds/m² (80, 69, 60 and 53 birds per pen). Mortality was higher at 18 birds/m² (7.8%) than at 12 or 13.6 birds/m² (6.2 and 5.7%). Over the whole study period feed consumption and body weight gain increased as stocking density/group size decreased. Feed conversion ratio was lowest (most efficient) in the groups with highest stocking density until eight weeks of age (possibly because of reduced movement in the pens) while at most ages after that point feed conversion ratio was lower in groups with stocking densities of 12 or 13.6 birds/m². It should be noted that feeder and drinker space per bird decreased as stocking density/group size increased in both studies, thus there are a number of conditions which could have mediated the changes in mortality and productivity. In guinea fowl reared for meat in floor pens at 15.6, 13.6, 12 or 10.7 birds/m², no significant effects of stocking density on mortality were detected but food conversion was less efficient at the highest density (Nahashon et al., 2009).

GF3. WELFARE CONSIDERATIONS: OVERVIEW

There is a lack of research on the effects of housing systems for guinea fowl. Based on research on closely-related farmed bird species, barren cage systems are likely to have adverse welfare consequences. Higher stocking densities (mediated by larger group sizes) have been associated with higher mortality, but further research is needed to establish recommended stocking densities, group sizes and sex ratios to ensure good welfare.

GF4. REFERENCES

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PHEASANTS

PHS1. INTRODUCTION

PHS1.1 Life history

The ring necked or common pheasant *Phasianus colchicus* is a gallinaceous bird native to central Asia and east Asia, but has been widely introduced as a game bird in the rest of the world (Hill and Robertson, 1988; Johnsgard, 1999, cited by Matheson et al., 2015), including Europe more than 1,000 years ago. Their preferred habitats in the UK are woodland edges (Robertson et al., 1993b) rich in shrubby cover, with seed bearing trees, bordering arable land. Preferred habitats in other countries are in areas of high diversity, including herbaceous cover and tall grassland (Robertson, 1996; Schmitz and Clark, 1999).

Like chickens and partridges, pheasants are gallinaceous with similar biology. All tend to walk rather than fly, though pheasants and partridges cover greater distances in flight than chickens. All species will perch and roost at night on low branches.

Pheasants are omnivores, with diets including invertebrates (Chiverton, 1999; Doxon and Carroll, 2010) as well as grain, seeds, berries, young shoots, corn, and sorghum (Bogenschutz et al., 1995). They are ground living, foraging by ground pecking, scratching and beak digging (Matheson et al., 2015). They also perform dust-bathing, and nest at ground level; nests are scrapes in the ground amongst the leaves and residual vegetation. However, outside the breeding season they will roost on low branches, and can make short flights to escape predators (Robertson et al., 1993a).

Pheasants are sexually dimorphic; the male is larger than the female. They are polygamous, with males defending territories and harems therein (Robertson et al., 1993b), leading to aggression during the breeding season. Females choose a male based on the quality of their territory and/or the quality of the male (Goransson et al., 1990; Robertson et al., 1993b), and females breed asynchronously, allowing all females in a harem to be inseminated by the same male (Goransson et al., 1990). Harem size varies between 1-5 females (Hill and Robertson, 1988). Females rear their young alone, distancing themselves from males to make a nest. In a survey on 1,384 nests in the UK clutch size ranged from 1-28 eggs, with a mean of 11.4 eggs per nest.

PHS1.2 Farming and rearing

Pheasant farming may have a complex structure, with a number of different housing systems in use. Pheasants are reared for release for hunting. Pheasants may occasionally be reared for meat production but no scientific papers were found on this aspect. Rearing for the game industry often takes place in large open pens, after brooding. However, in order to provide chicks for rearing, laying flocks must also be kept with both males and females. Laying flocks may be housed in cages, aviaries or open pens, and birds may be moved into different housing systems for the duration of their laying season. Thus pheasant farming presents a number of unique challenges, with potential welfare implications. Housing in cages may have similar implications to those for laying hens, in terms of facilitating behavioural needs. Aggression presents a particular problem where laying birds are housed in large flocks with multiple males, as males engage in territorial behaviours, guarding harems of females with threats, calling, wing flapping, chasing, sparring and pecking. Pheasants also engage in feather pecking and cannibalism, a problem which is also seen in laying hens. The conditions in which pheasants are managed and housed may also impact upon their behaviour and ability to use resources in the wild after release for hunting.

There is relatively little research available into these issues specifically for pheasants. The close phylogenetic relationship and similar ecological niche of pheasants and chickens means that it is likely that the two species will have similar behavioural needs, and concomitantly similar welfare concerns. Therefore some information can be extrapolated from chickens to pheasants.

PHS2. FEED AND WATER

Diet during rearing can affect the way in which pheasants use the resources available to them after release for hunting. Reduced efficiency in using these resources could be associated with stress as well as increased mortality, which in turn may reduce welfare.

PHS2.1 Feeding and release

Diet during rearing may affect welfare after release for shooting. Whiteside et al. (2015) reared 1,800 pheasants, over two years, from day-old to seven weeks of age. In 2012, 30 groups of 30 birds were reared with each of the three diets (10 groups per diet): a standard crumb; a standard crumb with 5% mixed seed; and a standard crumb with 1% live

mealworms. In 2013, 30 groups of 30 birds were reared with one of two diets (15 groups per treatment): standard rearing crumb or standard rearing crumb plus 1% mealworms and 5% seeds. Birds were transferred to release pens at seven weeks of age, and behaviour and survival in the wild were subsequently measured. For both years more birds were detected in the wild after a year or 18 months (2012 and 2013 cohorts, respectively) if they had been reared with more complex diets. Birds with more complex diets spent less time foraging and more time engaged in vigilance behaviours; they also handled live prey more efficiently, and had a shorter hind gut. Thus feeding uniform diets may impact the way in which birds use the resources available to them after release, which could result in stress for those birds, as well as increased mortality.

PHS2.2 Relationships with injurious pecking

Deficiencies in several aspects of diet are associated with an increased risk of feather pecking and cannibalism in pheasants, as they are for laying hens, which in turn is associated with reduced welfare. Increasing fibre content and maintaining appropriate protein and amino acid levels are associated with reduced feather pecking and cannibalism.

Several aspects of nutrition are thought to be associated with feather pecking in poultry. This association was reviewed by Kjaer and Bessei (2013), who highlighted some research specifically focused on pheasants. Dietary fibre may be important. Pullainen (1965, cited by Kjaer and Bessei, 2013) found that two flocks of breeding pheasants showed no cannibalism when oats were added to their ration. Similarly, Scott et al. (1954, cited by Kjaer and Bessei, 2013), found that adding oat hulls to the diet improved plumage condition in pheasants. Cain et al. (1984, cited by Kjaer and Bessei, 2013) found the opposite; they increased energy levels but decreased fibre and found an improvement in levels of cannibalism in pheasants. Dietary protein has also been associated with feather pecking in pheasants. Cain et al. (1984, cited by Kjaer and Bessei, 2013) compared diets containing 16, 19 and 22% crude protein, and found that the lowest protein level was associated with increased feather pecking in growing pheasants. Sirèn (1963, cited by Kjaer and Bessei, 2013) found that a surplus of the amino acid arginine stopped feather pecking and cannibalism, although other studies have not been able to replicate this result.

PHS3. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

PHS3.1 Perching

Provision of perches during rearing has a positive effect on cognitive, morphological and behavioural development. Perch provision decreases aggression during rear and may facilitate post-release survival. Birds reared without access to perches did not roost as frequently on elevated perches in the immediate post-release period.

The environment in which pheasants are reared can impact cognitive, morphological and behavioural development. Not only could this have implications for birds' ability to cope during the period for which they are housed in that environment, it also has implications for later life. If birds are reared in sub-optimal environments they may not be equipped to use available resources appropriately after release, in turn affecting their welfare during that period. Whiteside et al. (2016) reared 900 pheasant chicks in three environments: standard commercial rearing conditions (in the UK); standard conditions plus natural perches (hazel boughs); and standard conditions plus artificial perches (plastic piping). Ten groups of 30 chicks were housed separately for each treatment. During the rearing period birds reared without access to perches showed higher levels of aggression, were lighter with thicker tarsi, and made more errors during radial maze tests. Differences in morphology did not persist after release, while roosting on elevated perches was more common in the birds reared with access to perches, although this effect vanished six to seven weeks after release. Thus there is some evidence that provision of perches during the rearing period can affect the way birds interact with their environment both during rearing and after release. Perching in laying hens is considered to be a behavioural need, thus reduced perching or roosting in pheasants could result in reduced welfare.

PHS4. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

PHS4.1 Housing systems

Pheasants may be housed in a variety of management systems with a variety of impacts on their welfare. Laying pheasants may be housed in cages (conventional or enriched) or large open pens. Housing in conventional cages may impinge upon birds' abilities to fulfil behavioural needs, resulting in frustration and reduced welfare. Housing in open pens, where multiple males are present in the flock, may result in excessive aggressive behaviour, thereby reducing welfare. Management strategies such as installing sight barriers to reduce disturbances to courtship and mating, as well as providing refuges, may help to reduce this problem.

A number of housing systems are available for breeding and rearing pheasants. These include open pens and cages. Pheasants are only semi-domesticated, retaining much of their wild behaviour. Certain wild traits are valuable, due to the

practice of releasing pheasants for hunting, so there has been no direct selection for traits associated with domestication such as reduced fearfulness or ability to adapt to confinement. Thus, housing in barren cages may present particular welfare concerns. Matheson et al. (2015) reviewed specific welfare concerns for pheasants in barren cages. They noted that cages may prevent social behaviours such as crowing, used by males to defend their territory, potentially resulting in stress. As with laying hens, housing on wire floors presents a risk to foot health, and furthermore does not provide a suitable substrate for the ground pecking and beak digging behaviours associated with gamebirds, or for dust-bathing, which may result in frustration, as well as overgrowth of the beak, which would normally be worn down by these behaviours.

Voslarova et al. (2015, full text not available) examined the impacts of conventional cages versus cages enriched with two perches and a hideout, on the welfare of pheasant hens. The authors compared pheasant hens fitted with spectacles (see PHS5.2a for description) with pheasant hens without spectacles in enriched cages. They found those housed in conventional cages showed more movement, stereotypic behaviour and aggression, but less feeding, preening and feather pecking; however, without further information it is impossible to tease apart the effects of housing system and fitting spectacles, although the authors deem the former to be the main effect.

There are other welfare concerns for laying pheasants housed in open pens. Confining groups of pheasants, with multiple males, at relatively high stocking densities (see PHS5.1) may lead to excessive aggression and fighting, while barren pens may result in disturbances of courtship and mating, and a lack of refuge for males to retreat from aggressive interactions. Deeming et al. (2011) investigated the use of sight barriers in pens of breeding pheasants to tackle these problems. They compared behaviours of birds during their first breeding season in 11 pens with sight barriers (tin sheeting and straw bales to a height of 60 cm) with that in 11 standard commercial pens. All pens had 56 females and 8 males at a stocking density of 2.73 m² per bird. Observations during the 10 week laying season showed that birds from pens with barriers showed less plumage damage. Perching was more common in pens with barriers, while preening was observed less frequently in these pens. Frequency of aggressive interactions was twice as high in pens without barriers; bird-to-bird pecking was also more frequent in these pens.

PHS5. MANAGEMENT AND HANDLING

PHS5.1 Stocking density and group size

Stocking density and group size are thought to be associated with feather pecking and cannibalism, and therefore reduced welfare. High stocking densities and group sizes are associated with increased plumage damage.

Kjaer (2004) examined the effects of stocking density and group size on plumage damage, as a proxy measure for feather pecking and cannibalism during rearing in aviary housed pheasants. Pheasants were housed in groups of 80 or 240 birds at three different stocking densities: 0.7, 1.3 or 4.0 birds/m² from day old to six weeks of age, with four replicates of each stocking density and group size treatment combination (except 240 birds at 0.7 birds/m², which had only two replicates). For 30 randomly chosen birds from each group, plumage was scored one to four (worst to best) at five to six weeks of age, and any wounds or skin damage were recorded at the same time. Total plumage score increased with stocking density, but was unaffected by group size. There were also more injuries to the skin in the highest stocking density and group size conditions, and birds grew more quickly at the two lower stocking densities. Cain et al. (1984, cited by Kjaer and Bessei, 2013) compared stocking densities of 1.4, 2.6 and 5.3 birds/m² for grower birds after brooding, and similarly found that feather pecking increased with stocking density. It is clear then that stocking density in particular, can have an impact on pheasant welfare, although care should be taken in extrapolating these results to older birds or birds in different housing systems.

PHS5.2 Procedures

PHS5.2a Beak trimming, spectacles and bits

Feather pecking and cannibalism can both significantly reduce pheasant welfare. A number of procedures are commonly used successfully to tackle these behaviours, including beak trimming, and fitting spectacles or bits. However, these procedures have welfare implications themselves; beak trimming is painful and may have long term behavioural impacts. Fitting both spectacles and bits appears aversive to the birds, and can result in damage to the beak and nares. Fitting spectacles has long term implications for stress in pheasants. Consequently the balance between preventing feather pecking and cannibalism, and subjecting birds to these treatments must be carefully assessed.

Pheasants may be subject to a number of procedures in order to prevent or reduce the effects of feather pecking; these include beak trimming, and fitting pheasants with bits on their beaks (Figure PHS1) during rearing or spectacles (Figure PHS2) in laying pens. Beak trimming is carried out much as for laying hens, with the same welfare implications in terms of pain and behavioural changes, and aims to remove the sharp tip of the beak in order to reduce the damage caused by feather pecking. Plastic bits are commonly fitted to pheasant chicks in the UK around three weeks of age and prevent the birds from fully closing their beaks, thus preventing damage due to feather pecking. Another approach is to fit solid plastic

blinkers (commonly termed “spectacles”) to obscure the birds’ forward vision. These spectacles are similarly fitted to the beak when birds are placed in laying pens. While all may be effective in preventing, or reducing damage due to, feather pecking and cannibalism, they also present their own welfare implications.



Figure PHS1: Pheasant with ‘bit’


Figure PHS2: Pheasant with ‘spectacles’

[Photographs used with the permission of the Game & Wildlife Conservation Trust, UK: www.gwct.org.uk]

Voslarova et al. (2013) examined the effects of wearing spectacles and beak trimming in ten month old pheasants. Pheasants were reared in four outdoor aviaries with a mean flock size of 200 birds at a stocking density of 1.3 birds/m²; before the beginning of the laying period 20 pheasants (10 males, 10 females) were randomly selected for each treatment group (beak trimming, spectacles, control); short term effects on biochemical indices of stress were examined; blood samples were collected immediately after treatment. In order to analyse the long-term effects, pheasants were housed in cages from the beginning of their laying period in groups comprising one male and five females; cages were randomly assigned to one of three treatments which were implemented immediately before placement in cages (beak trimmed, spectacles, control; 150 cages, 50 per treatment). For each treatment blood samples were collected from 15 randomly selected birds in 15 different cages at the end of the laying period, three months after treatment. In the short term both beak trimmed pheasants and those fitted with spectacles had higher concentrations of plasma corticosterone and lactate dehydrogenase, and lower concentrations of plasma cholesterol and triglycerides compared with control birds. Beak trimmed pheasants also had lower concentrations of aspartate aminotransferase (AST), and pheasants fitted with spectacles had lower concentrations of lactate, compared with control birds. At the end of the laying period beak trimmed birds had higher plasma concentrations of neopterin compared with both control and spectacled birds, while spectacled birds had lower plasma concentrations of biopterin compared with both control and beak trimmed pheasants. Hens fitted with spectacles also had higher counts of leukocytes, heterophils, lymphocytes, eosinophils, basophils and monocytes, while beak trimmed birds had higher counts of eosinophils and monocytes, compared with control birds. Spectacled birds also had higher heterophil/lymphocyte ratios than beak trimmed birds. Thus, differences in blood biochemistry in the short term indicate that both beak trimming and fitting with spectacles are stressful procedures, although the reaction to beak trimming was greater. Conversely the long term effect on biochemical indices of stress was greater for pheasants fitted with spectacles than for beak trimmed pheasants. It may be that while beak trimming is more invasive and painful in the short term, feeding and pecking behaviour adapts, thus the long term impact is less than in the case of fitting spectacles, where vision continues to be impaired for the duration of the laying period.

Butler and Davis (2014) also examined the effects of fitting pheasants with spectacles on 23 game farms across England in 2006 and 2007. Laying birds were examined in both flock (multiple males and females) and harem (one male housed with approximately eight females) management systems. On each farm two identical pens were stocked with day old pheasant chicks and randomly allocated to a treatment group: spectacled or non-spectacled. All other management was identical for the two pens. Fitting female pheasants with spectacles did reduce bird-to-bird pecking, improve feather condition and reduce skin damage in the flock management system; however, the practice also reduced the performance of other normal behaviours (perching and foraging), and increased head shaking and scratching suggests birds found them to be aversive. Further, females fitted with spectacles were also more likely to have damage to the beak or nares compared with non-spectacled females.

Butler and Davis (2010) collected data from 18 game farms in England between 2005 and 2007. Using the same methods as described above pens of bitted (at 10-32 days of age) or non-bitted pheasants were compared. Again biting birds was associated with reduced bird-to-bird pecking and skin damage, and improved feather condition from two to five weeks of age. However, bitted birds were two times more likely to be observed head shaking or scratching, again suggesting the



birds find them aversive. Further, as with spectacles, the proportion of bitted birds with abnormalities to the beak or nares, increased to 12.5% by five weeks of age in bitted birds compared with no abnormalities in non-bitted birds.

In summary, while all three methods appear to reduce the damage due to injurious pecking, it is clear that all procedures also have negative welfare implications that must be balanced against the risks of feather pecking and cannibalism. Other methods of reducing or controlling feather pecking and cannibalism should be sought.

PHS6. WELFARE CONSIDERATIONS: OVERVIEW

There is little reliable research on the impact of housing pheasants in cages; however, housing in conventional as opposed to enriched cages appears to have adverse effects on both health and behaviour. The provision of furnishings such as perches in all systems, and additional hideouts to reduce aggression in pen systems, have clear welfare benefits. Higher stocking densities appear to have adverse effects on welfare but research is needed to establish recommended stocking densities, group sizes and sex ratios to ensure welfare.

Welfare post-release for hunting may also be affected by management in captivity. The diet and enrichments (such as perches) provided in captivity may affect the way in which birds are able to use the resources available to them after release. An inability to use these resources efficiently could cause stress in released birds, as well as increased mortality.

Feather pecking and cannibalism present a significant welfare problem. While the methods employed for reducing or preventing these behaviours in pheasants appear to be effective, they have significant welfare implications in their own right. Consequently it would be preferable if beak trimming, and fitting spectacles and bits were used only as a last resort. In the first instance welfare could be improved by reducing the risks of feather pecking by other methods, such as appropriate levels of fibre and protein in the diet, minimising stocking density and using sight barriers in open pens. Farmers may also consider the management techniques suggested for reducing injurious pecking in laying hens. Further it is also important to ensure that beak trimming, where necessary, is carried out with the least impact on welfare, at the earliest possible age and using infra-red trimming methods, as for laying hens.

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PARTRIDGES

PTR 1. INTRODUCTION

PTR1.1 Life history

Partridges are medium sized non-migratory gamebirds. While closely related to pheasants, they are smaller in size and typically dull coloured in comparison, with none of the ornamentation seen in their relatives (Kimball et al., 1999). Originating in Eurasia (Ekarius, 2007), partridges are widely distributed across Asia, Europe and Africa (Kimball et al., 1999). Worldwide, there are 106 known species of partridge (Ekarius, 2007).

The preferred habitats of partridges are farmed fields with adjacent woods or hedgerows (Ekarius, 2007). It is these uncultivated areas at field boundaries that form the core of the home range, from which the partridges will venture out to exploit neighbouring agricultural fields (Šálek et al., 2004; Buner et al., 2005). Partridges nest in perennial plant cover, for example shrubs or herbaceous stands (Buner et al., 2005). This provides them with an abundant source of invertebrates with which to feed their chicks as well as protection from predators (Buner et al., 2005; Kuijper et al., 2009). Partridges eat mainly seeds and forage, but also some insects, with invertebrates providing an important source of protein for young chicks (Buner et al., 2005; Ekarius, 2007; Kuijper et al., 2009).

The social organisation of the partridge varies with season (Buner et al., 2005). Adult breeding pairs occupy home ranges in spring and summer, after which the young generally remain with them forming a family group (covey) until late winter or early spring the following year (Buner et al., 2005).

PTR1.2 Farming and rearing

As is the case for pheasant farming, partridge farming can take different forms. Breeding groups may be housed in large outdoor pens, smaller indoor pens, or indoor or outdoor cages. Chicks may be reared naturally, with their parents, or artificially after incubation in an incubator without access to adult birds. Rearing may be in any of the above housing systems. Birds are reared for meat, either being released for hunting purposes, or being fattened and taken for slaughter directly from the farm. Housing in cages and/or without access to adult birds may have similar welfare implications as those highlighted for laying hens. Mating presents a particular area for concern, since breeding partridges mate monogamously for the duration of each breeding season. The pairing is mediated by female choice and the way these pairings are facilitated in captivity can have important effects. Also, as is the case for pheasants, conditions in captivity, e.g. diet and experiences during rearing, may have important effects on the birds' ability to adapt and survive after release for hunting. Survival of partridges that escape shooting after release can be extremely low – mean survival times of 9.4 and 7.6 days (Alonso et al., 2010) or 18 days (Gaudioso et al., 2011) – and it would be beneficial to research rearing practices that could increase the chances of birds surviving with good welfare post-release.

There is relatively little research dealing with specific welfare issues for partridge. Although much smaller than laying hens or pheasants, all are gallinaceous birds, with similar behavioural repertoires. All are ground living, pecking and scratching at the ground while foraging. All tend to walk rather than fly, though pheasants and partridges cover greater distances in flight than chickens. All species will perch and roost at night on low branches. Partridges have not been subject to the same level of domestication as chickens, and tend to be flightier. Despite this, their close phylogenetic relationship and similar ecological niche means that is likely that two species will have similar behavioural needs, and concomitantly similar welfare concerns.

PTR2. FEED AND WATER

Several aspects of diet have been associated with welfare consequences for partridges. Commercial diets are relatively low in fibre and n-3 polyunsaturated fatty acids, and lack invertebrates, when compared with natural diets. Low fibre diets have important physiological effects, while low n-3 diets are associated with impaired learning. Diets high in invertebrates lead to heavier, better feathered chicks. All of these deficiencies could impair health and welfare both in captivity and after release for hunting. The method of feeding is also important. Feeding unpredictable diets both pre- and post-natally may affect stress responses, and can improve ability to cope with a wild environment, and thus improve welfare after release for hunting.

PTR2.1 Diet composition

A survey carried out by Wiberg and Gunnarson (2007) of Swedish game birds found that the majority of farmed grey partridge were fed commercial feeds, including feeds formulated for pheasants and turkeys. Thus feeds may not be formulated specifically to meet the needs of the partridge. Furthermore, although well balanced for other nutrients such feeds often have a low fibre content. Millan et al. (2003) compared red-legged partridges during rearing fed a commercial

diet, diluted with whole wheat (2-3.9% fibre, and less than 3.3% fat) with a treatment diet containing 8% fibre and 8.2% fat. Control birds at six months of age had a higher spleen weight, lower gizzard weight, and shorter small intestine. They also had higher plasma concentrations of protein, glucose (males), cholesterol, and triglycerides. Thus concentrated commercial diets could have important physiological effects, with potential impacts on health in captivity, and ability to utilise natural diets efficiently after release for hunting, which may reduce both welfare and survival. However, when Kjaer and Hansen (2007) fed 80 pairs of grey-legged partridge one of each of four treatments (20 pairs each): control or control with either maize silage, fresh rucola salad or wheat sprouts, they found few behavioural differences between treatment groups, and little aggression or feather pecking (expected in stressful conditions). They also found that birds fed wheat sprouts tended to have a greater corticosterone response to a stressful event (crating) compared with all other groups, and that they produced significantly fewer eggs. Thus they found no evidence for a reduction in welfare associated with feeding concentrate only diets.

Another difference between captive and natural diets for partridge is the invertebrate content. Liukkonen et al. (2002, full text not available) examined the effect of three diets on grey-legged partridges: *ad libitum* plant based diet plus either high invertebrate, low invertebrate or fish. Chicks fed the diet high in invertebrates were heavier and their primary feathers developed earlier, with the result that those chicks did not cool as fast as chicks in the other treatment groups. Again this has welfare implications, as it could affect survivability both before and after release for hunting, or response to ambient temperature in partridges reared on-farm for meat.

Fronte et al. (2008) examined the effect of differing concentrations of n-3 polyunsaturated fatty acids (PUFAs) in maternal diets on learning ability in one day old red-legged partridge chicks. Parents were fed three different diets from 30 days before the start of the laying period: 30 g/kg palm oil; 15 g/kg mixed oil (60% linseed oil, 40% fish oil); or 30 g/kg oil mixture, in order of increasing n-3 concentration. Chicks of hens fed the 15 g/kg mixed oil diet showed better memory retention than those of hens fed the palm oil diet, which could affect behaviour in captivity and survival of those released to the wild, thus reducing welfare.

PTR2.2 Food presentation

As well as diet composition the way in which feed is provided may affect partridge welfare. In the wild partridges would experience an unpredictable food supply, thus providing a predictable commercial feed could cause stress in the birds in captivity, as well as leaving birds unprepared for foraging in the wild after release. Homberger et al. (2013) compared pre- and post-natal provision of unpredictable feed with predictable feed in two strains of grey-legged partridges. Twenty-five breeding pairs of each strain were placed in outdoor aviaries and randomly assigned to a predictable (feed available *ad libitum* 24 h per day) or unpredictable (feed removed at a random time for 4 h per day) feed supply. The unpredictable feed supply regime was implemented from one week before egg laying began. Chicks were housed in indoor aviaries and provided with feed *ad libitum* for one week post-hatch. Each aviary included an equal number of birds from each strain pre-natal feed treatment combination. Aviaries were randomly assigned to unpredictable feed supplies, which were implemented by withdrawing feed and water for 3 h at random times once a day from seven to 29 days of age. Immune response was increased in chicks with an unpredictable post-natal feed supply, and birds of the wild strain exhibited a higher glucocorticoid stress response when supplied with predictable pre- and post-natal diets. Oxidative stress response was also higher in wild strain chicks from predictable pre- and post-natal treatments compared with the domesticated strain in predictable feed treatments. Thus provision of an unpredictable feed supply, both pre- and post-natally appears to have welfare benefits. However, in a similar experiment Homberger et al. (2015) found a higher corticosterone response to a stressor in chicks subject to an unpredictable pre-natal food supply, hypothesising that this may be an adaptive maternal response to support homeostasis in chicks in a changing environment. Thus, the effect of feeding predictable versus unpredictable diets on biochemical markers of stress appears variable. However, Homberger et al. (2014) in another similarly designed experiment examined post-release survival of grey-legged partridge and found that survival rate was higher in birds which had experienced an unpredictable diet postnatally. Such birds may be better prepared to deal with the wild environment and thus experienced improved welfare post-release.

PTR2.3 Relationship with injurious pecking

Deficiencies in crude protein concentration in the diet are associated with an increased risk of feather pecking and cannibalism in partridges, as they are for laying hens, which in turn is associated with reduced welfare. Maintenance of appropriate protein levels is associated with reduced feather pecking and cannibalism.

As for laying hens and pheasants, partridges exhibit feather pecking behaviours. Blake et al. (2013) investigated the effect of crude protein content of the diet on feather pecking in the Hungarian partridge. Sixteen pens with 35 chicks each were randomly assigned to one of two crude protein (high and low) and one of two lighting treatments (10 lux or 20 lux) from 0-13 weeks of age. High crude protein levels were 30%, 26% and 22% from 0-4, 4-8 and 8-13 weeks of age, respectively, while low crude protein levels were 26%, 22% and 18% for the same ages. Plumage condition was significantly worse in the low crude protein condition, suggesting birds in this treatment performed more feather pecking. Thus protein levels must be carefully monitored in order to manage the risk of feather pecking.

PTR3. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

PTR3.1 Cages

Housing partridges in barren cages for the duration of the breeding season has become more common. Such environments may be associated with risk of physical injury (e.g. to feet and wings as a result of standing on wire floors and wing flapping in a confined space) as well as frustration due to the inhibition of natural behaviours such as ground pecking, beak digging and dust-bathing. Thus welfare may be significantly reduced in these housing systems.

A number of different housing systems are available for housing partridges. They may be housed in open grass pens, in aviaries or in cages at any stage in their life cycle. Each of these present their own challenges in terms of bird welfare, although there is little research examining these challenges in detail. Matheson et al. (2015) reviewed the potential implications for partridges housed in cages, noting that since these birds are only semi-domesticated they retain wild behaviours including flying characteristics, which may make them particularly unsuited to housing in barren cages, which may inhibit wing flapping behaviours. Other welfare implications discussed by Matheson et al. (2015) include those of housing the birds on a wire floor. As with laying hens this presents a risk to foot health, and also does not provide a suitable foraging or dust-bathing substrate for the ground pecking and beak digging behaviours associated with gamebirds this may result in frustration, as well as overgrowth of the beak, which would normally be worn down by these behaviours. Partridges are often housed in pairs in cages over two breeding seasons, whereas in the wild pairs would disassociate, returning to flocks at the end of the breeding season. Therefore, housing in this way may cause stress (Matheson et al., 2015).

PTR4. FEAR AND DISTRESS

Hybrid birds show less evidence of fear and stress in captivity, thus those birds may be better suited to farming, with higher welfare than pure breed birds in captive conditions.

Hybrid species of partridge may be preferred by game farmers as they are heavier and have a longer laying period. Campo et al. (2015) compared levels of fear and stress in 66 hybrid versus 66 pure breed red-legged partridges at 52 weeks of age. Birds were housed in single-sex groups of three in outdoor cages. Pure breed birds exhibited longer durations of tonic immobility and higher heterophil to lymphocyte ratios, and higher fluctuating asymmetry in toe length. This indicates that pure breed birds are more stressed and thus have reduced welfare in captivity, when compared to hybrid birds.

PTR5. SENSORY ENVIRONMENT

PTR5.1 Lighting

Light intensity is associated with feather pecking in partridge. Higher light intensities are associated with worse plumage condition, and therefore more feather pecking and reduced welfare.

There is a well-established, if not comprehensively understood, effect of lighting on feather pecking in laying hens. In the experiment described above (see PTR2.3), Blake et al. (2013) examined the effect of light intensity (and crude protein) on feather pecking in the Hungarian partridge. Feather condition was significantly better in the 10 lux treatment compared with the 20 lux treatment. Light intensity is therefore an important consideration when managing feather pecking and therefore welfare on farm.

PTR6. MANAGEMENT AND HANDLING

Variability exists in partridge management practices such as pairing (forced or free) and rearing with or without access to natural stimuli (e.g. adult birds and predators); thus management may be more or less natural. Forced pairings are associated with increased aggression and injury, and reduced normal behaviour, which implies a reduction in welfare. Rearing with access to natural stimuli including parent birds and experience of predators may promote the development of normal and appropriate behaviour both in captivity and after release for hunting, with a concomitant increase in likelihood of survival after release.

PTR6.1 Pairing and breeding group management

There are several aspects of management which may have an impact on partridge welfare. Natural breeding systems allow natural mating, with pairs forming as a result of females choosing a partner. Artificial breeding systems use forced mating, during which males and females are simply paired, usually in cages. Natural rearing systems allow breeding pairs

to incubate, hatch and rear their own chicks, while in artificial systems eggs are removed to incubators after laying, and hatched and reared without access to parent birds.

Aggression is more common in forced pairings. Prieto et al. (2012) examined the behaviour of 10 month old red-legged partridge in two types of pairs: 24 the product of free pairing, and 24 the product of forced pairing. Birds in forced pairs performed more aggressive behaviours (males directing aggression towards females) both during the pairing and laying periods. Although there were no significant differences identified between the two groups in number of injuries 10 pairs were removed from the experiment due to welfare concerns: six from forced and four from free pairs. Six females died and five of those were from forced pairings, thus there is some suggestion that injuries may be more common in forced pairs. Thus forced pairing appears to present a high risk of reduced welfare. Furthermore, Alonso et al. (2008) compared the behaviour of 40 pairs of 10 month old red-legged partridges, 20 the product of forced pairing, and 20 the product of free pairs (one female chose between four males). Although free pairing couples spent less time together with a distance of <50 cm between them, they also spent more time engaged in nesting behaviours, and performed more cohesive behaviours, pecking together and being alert together. Aggressive behaviours were very rare, but only observed in the forced pairs, with males directing aggression towards females. Increased cohesive and nesting behaviours were associated with increased reproductive success. The authors also suggest that the higher frequency of performing natural behaviours may be indicative of better welfare in free pairing couples.

PTR6.2 Natural and artificial rearing

Natural versus artificial rearing may also have important implications for behaviour. Rearing laying hens with a broody hen is known to affect behaviour; Shimmura et al. (2010) found rearing with a broody hen promoted behavioural development and reduced the performance of abnormal behaviours such as feather pecking. It is not unreasonable to think the same effects may be observed in partridges. There is also the potential for an important impact of rearing in captivity on behaviour and ability to adapt to conditions in the wild after release for hunting (Alonso et al., 2005; Perez et al., 2010). Santilli et al. (2012) compared the post-release survival of naturally versus artificially reared red-legged partridges in Italy. Breeding birds (25 males and 25 females) were housed in a 4,000 m² pen with shrubs and grass as ground cover. Birds were allowed to mate and rear chicks naturally. Artificially reared chicks were sired by force-mated pairs housed in cages; eggs were hatched in an incubator. Young birds were released into the wild from both naturally and artificially reared groups; survival of naturally reared birds was 2.2x, 2.5x, and 2x that of artificially reared birds at one, three and six months after release, respectively (although the authors did not find this difference to be statistically significant). Sanchez-Garcia et al. (2016) compared the behaviour of tutored and untutored red-legged partridge chicks. Chicks were incubated and hatched artificially, and were reared in brooding pens where adult tutor birds were introduced, initially in cages, and then allowed to mix with the broods at 7-10 days of age. Reactions to a raptor model and a human were examined. The tutors had prior experience of these stimuli and gave appropriate aerial or ground-predator warning calls on over 75% of trials. Although chicks trained by tutors and non-trained chicks exhibited similar motor responses to both tests, stronger (all chicks responded more frequently) and more sustained (longer latency for ≥50% of chicks to return to normal behaviour) responses were observed in the trained chicks. Thus chicks reared with tutors may be better prepared to deal with predators when released for hunting, which may improve welfare post-release.

Experience of predators during rear may also affect post-release survival. Zaccaroni et al. (2007) artificially incubated, hatched without visual contact with humans, and reared rock partridges in two groups of 250. All chicks were inspected daily by the same operator, but in the experimental group from the age of 3-5 days a different person entered the room shouting and waving. The control group did not receive these visits. From 35 days of age all birds were housed in groups of 30 in outside cages, where they could not experience potential predators, and the only human interaction continued to be daily inspection by the same person. Reactions to an approaching human or a simulated raptor or fox were examined. Birds from the experimental group performed escape reactions in response to an approaching human when the human was further away than the control group. However, there was no difference between the experimental and control groups in reactions to either the raptor or fox simulation. This may mean that reactions to these predators are so innate that early experience of predators has no impact. Alternatively, it may suggest that it is important for birds to experience specific predators to learn appropriate predator avoidance behaviour, which may impact survival and welfare after release.

PTR6.3 Stocking density and group size

High stocking densities in cages are associated with increased mortality and therefore reduced welfare.

Stocking density can have an important impact on welfare, affecting the behaviours animals are able to perform, as well as their ability to move away from aggressive individuals. There is little information on the most appropriate stocking densities at which to house partridges. Gunlu et al. (2007) reared rock partridges in cages at four different stocking densities mediated by group size: 576.9 cm²/chick; 384.6 cm²/chick; 288.5 cm²/chick; and 230.8 cm²/chick (group sizes of 26, 39, 52, 65 chicks, respectively). Four cages of each stocking density were populated with newly hatched chicks to be reared for meat for a 12 week period. Mortality increased with stocking density; cumulative mortality at 12 weeks was 3.5%, 3.8%, 6.8% and 13.0% from lowest to highest stocking density. Thus mortality at the two lowest stocking densities

was similar, but doubled at 288.5 cm²/chick, and doubled again at 230.8 cm²/chick, suggesting the two highest stocking densities may be particularly detrimental to welfare.

PTR6.4 Procedures

As for pheasants, partridges may be fitted with beak bits to prevent feather pecking. It is likely that partridges experience the same negative welfare consequences of biting as pheasants. Beak bits have also been associated with beak infection and necrosis which reduces welfare.

As with laying hens and pheasants, partridges perform feather pecking behaviours, and like those species various methods of preventing or reducing the effects of feather pecking are routinely used. As for pheasants, beak bits may be fitted to partridges to prevent them fully closing their beaks and thus reduce the damage they are able to cause through feather pecking. Various negative welfare consequences of fitting bits to pheasants are outlined in the pheasant section (PHS5.2a); less work has examined the effects of biting in partridges, although it is not unreasonable to assume the consequences may be the same. Brower et al. (2010) present a case report concerning three adult male partridges with beak lesions, submitted for necropsy from a commercial farm where they had been reared in groups of 120-150 in wire mesh indoor pens. Lesions infected with cutaneous poxvirus had developed centred on the nares of the affected birds; beak necrosis and in some cases complete loss of the upper beak followed. The spread of the infection was facilitated by the presence of beak bits in the nares. This represents a specific negative welfare consequence of the use of beak bits.

PTR7. WELFARE CONSIDERATIONS: OVERVIEW

Diet composition is important for partridge welfare, as these birds are adapted to eat diets with a relatively high fibre, n-3 polyunsaturated fatty acid and invertebrate content. The provision of commercial low fibre feeds designed for other farmed bird species has adverse effects on partridge welfare in captivity and birds reared with such diets may also have compromised welfare and survival if released to the wild for hunting purposes.

Housing in cages, particularly barren, unenriched cages is likely to present challenges to welfare. The semi-domesticated partridge retains an instinct to fly, which cannot be fully expressed without injury in cage housing. Furthermore, as is the case with laying hens, behavioural needs such as ground pecking, beak digging and dust-bathing, may be prevented in caged birds, leading to frustration and reduced welfare. Stocking density is also important, with higher stocking densities associated with increased mortality.

Feather pecking is a welfare problem for partridges. Low levels of crude protein in the diet and high light intensities are risk factors which have been specifically identified in partridges. Beak biting is used as one method of preventing or reducing feather pecking; however, as with pheasants fitting beak bits presents welfare challenges. Other means of reducing the risk of feather pecking should be investigated, and may be extrapolated from literature concerning laying hens.

Mating is another area of concern for partridge farming. In the wild females choose a mate at the start of the breeding season, and that pair remains together for the duration of a breeding season. Whilst some farming systems allow mating to occur in this way, many used forced mating, where males and females are simply paired by the farmer. This system can lead to increased aggression in the male, directed towards the female, with an increased risk of injury particularly for the female. Forced mating is also associated with reduced reproductive success. The free mating system should be used where possible.

A number of factors including the method of feed provision (predictable or unpredictable), as well as the birds' experiences during rearing (exposure to adult birds and predators) may affect birds' ability to adapt and survive after release into the wild for hunting. Birds that cannot adapt to wild environments will experience reduced welfare, and thus management systems which mimic natural rearing should be favoured where possible.

Finally, the limited research available on partridges has been conducted on a variety of different species and the extent to which findings on one species can be applied to others is not known. This should be borne in mind when discussing the welfare of farmed partridges.

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PIGEONS

PGN1. INTRODUCTION

PGN1.1 Life history

Domestic pigeons are descended from wild rock doves (*Columba livia*) and may be kept and bred for meat, for racing, or for breeding and showing. Feral pigeons, originating from domestic populations, have successfully colonised many urban areas around the world. These feral birds have been the subject of considerable scientific study, often with the underlying aim of gaining a greater understanding of their biology and habitat interaction to better control their populations. Due to the differences in natural biology, extrapolating from the literature for chickens is likely to be of limited use.

A study of one of the few remaining populations of wild rock doves described how the birds lived in a colony of around 3,000 birds on sea cliffs in Sardinia. Every day the birds left the colony in small flocks (larger in winter, reaching up to 40 birds) to forage for food for several hours a day. In spring and summer most birds left shortly after sunrise, with another peak in the afternoon, and in autumn and winter the birds were most active in the afternoon. They followed set routes and travelled up to 19 km to reach agricultural feeding sites (Baldaccini et al., 2000). When food is available nearer both wild and feral rock doves will access nearby sources (Baldaccini et al., 2000; Soldatini et al., 2006). Pigeons eat grains, seeds and a great variety of other foods, and have been particularly successful at colonising urban areas due partly to their ability to eat a range of food waste associated with humans (Morand-Ferron et al., 2009). Feral pigeons have developed breeding strategies to maximise their use of plentiful food supplies, including being able to breed throughout the year, in contrast to wild birds (Baldaccini et al., 2000; Harris et al., 2016; Stock and Haag-Wackernagel, 2016). Pigeons form monogamous pairs and each parent helps build a rudimentary nest on natural rock or buildings in which to lay usually two eggs, incubate them and raise the fast-growing squabs (Hetmanski and Barkowska, 2007).

PGN1.2 Farming and rearing

Pigeon fanciers (and traditional farming) usually allow free or daily access to outdoor flights, and this is also recommended for laboratory pigeons, along with shelves and ledges to replicate the wild-type environment (Hawkins et al., 2001). These, and local training flights, are generally thought to improve homing ability and/or attachment to the colony in young birds. Stamina for racing (and hence perhaps overall health) is improved. Pigeons are usually kept in medium sized flocks (10-100 birds), in which dominance hierarchies are common, and older/dominant individuals command habitual roost perches higher in the loft. For racing, birds are sometimes temporarily “widowed” to increase homing motivation, suggesting that attachment to mate and nest are powerful motivators and may lead to reduced welfare if deprived for any length of time. Despite this wealth of folk-knowledge, there is little published work on the housing and social needs and requirements of farmed pigeons.

PGN2. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

PGN2.1 Enrichment

Four papers were identified in the literature search where an ‘enriched’ captive environment was used as part of an experimental study to compare to a small, barren, singly housed environment. Welfare *per se* was not studied, the welfare benefit being implied, and all had a positive impact on brain development, cognition or choice-taking behaviour. The enrichments provided in each study were: access to three other conspecifics in an otherwise barren, but larger, environment (2 studies) (continuous for 60 days) (Laude et al., 2016) and short term (4 h/day for 90 days) (Pattison et al., 2013); artificial flowers, balls, tubes and visual contact with neighbours (Melleu et al., 2016); a device to encourage foraging in singly housed pigeons (Turner, 2010).

PGN3. WELFARE CONSIDERATIONS: OVERVIEW

The paucity of literature about farmed pigeon welfare makes it difficult to draw firm conclusions about their needs and the effect of captivity on them. Given the apparent increasing interest in farming pigeon squabs for meat in Australia (ABC, 2014) it would seem timely to conduct good quality research into the welfare of these birds. In the absence of such studies it is recommended that attention is paid to the natural biology of pigeons to provide guidance on how best to keep them in captivity. In particular, pigeons should be provided with the opportunity for flight, fed a varied grain-based diet and have access to a nest suitable for a pair of birds to raise fast-growing squabs.

PGN4. REFERENCES

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QUAIL

Q1. INTRODUCTION

Q1.1 Life history

Domestic quail, bred from Japanese quail (*Coturnix japonica*), are farmed for meat and eggs throughout much of the world. Despite an increase in size and egg production domestic quail are not genetically or behaviourally markedly different from wild birds (Schmid and Wechsler, 1997; Chang et al., 2009). Frequently farmed quail are group-housed in intensive conditions with little enrichment and may be subject to beak reduction. Quail have been a model species for much fundamental experimental work aiming to understand the biological basis for stress responses, emotional reactivity and sociability, with genetically diverging lines often being utilised in such studies.

In the wild Japanese quail are small, ground-nesting, grain and insect-eating birds originating from East Asia. Under semi-natural conditions they show a strong preference for spending time in areas of vegetative cover (48% of time vs 17% of floor area with cover) as well as laying eggs in cover (Schmid and Wechsler, 1997). These quail spent much of their time walking/running (24%) and pecking/scratching (8%) in likely foraging activity. Although a migratory bird, under semi-natural conditions during the breeding season, flight was rarely observed, as was perching, even at night. 'Close relationships' formed between some pairs of birds during the breeding season but broke up when breeding was over. Chasing and pecking other birds, sometimes resulting in severe injuries, were most commonly observed between cocks, and never between two hens (Schmid and Wechsler, 1997). Preening and dust-bathing occurred frequently (12% and 2% of time respectively) and dust-bathing mostly occurred on soil (Schmid and Wechsler, 1997).

Quail are thus similar to hens in being ground dwelling and nesting, rarely flying, eating grains and insects and engaging in dust-bathing. However, they differ from hens in their social structure and by remaining on the ground, not perching, at night. These biological differences should be borne in mind when extrapolating from welfare literature on chickens.

Q2. RISK MANAGEMENT

Q2.1 Injurious pecking

Groups of quail may show aggressive pecking, particularly to the head, and signs of feather loss and injuries due to pecking (Taskin and Camci, 2017). Aggressive pecking in male quail can be a significant welfare problem due to serious head injuries (Wechsler and Schmid, 1998). Varying environmental variables (visual barriers, age of introduction to pens, ratio of hens to males, light intensity) did not reduce serious head injuries in multi-male groups. In single-male groups no serious injuries were noted and high rates of fertilised eggs were obtained. For these reasons, Wechsler and Schmid (1998) recommended that multi-male breeding groups should not be used. Mixing groups of male quail by adding an unfamiliar bird increases aggression (Edens et al., 1983; Francois et al., 2000). It may be possible to select for reduced aggression in males but the impact of the environment on associated traits appears to be important (Nol et al., 1996).

Q3. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

Q3.1 Enriched vs barren cages

Quail reared in groups of eight in an 'enriched aviary' rather than a 'battery cage', in an attempt to mimic possible commercial conditions, showed a marked welfare benefit. The enriched aviary had a larger size and therefore lower stocking density (5.2 vs 29.6 quail/m²), height that allowed for flying (162 cm vs 27 cm), 2.5 cm sawdust bedding, sand-bathing area of 0.30 x 1.10 m, three perches and two wood nests measuring 0.25 x 0.11 x 0.10 m. Feed, water, lighting and temperature were identical between the systems. Quail in the enriched aviary engaged in fewer agonistic behaviours and utilised the sand bath and occasionally the opportunity for flight (see Table Q1). Perching was not observed. Several haematological parameters, including reduced heterophil/lymphocyte ratio, were significantly better in the enriched aviary. However, faecal glucocorticoid was significantly higher in the enriched aviary, suggested by the authors to be due to a greater level of disturbance to the birds required to collect samples in the aviary (Nordi et al., 2012).

Table Q1: Ethogram of 12 quails per treatment, in battery cages or enriched aviaries, two days of observation, 11 consecutive hours during the light period (Nordi et al., 2012)

Behavioural activity	Number of observations, instantaneous sampling (Ethogram, %)	
	Battery Cage	Enriched Aviary
Eating	560(13.32)	375(8.41)
Drinking	112(2.66)*	55(1.23)*
Agnostic behaviour	94(2.24)*	24(0.54)*
Wing flapping	5(0.12)	1(0.02)
Open beak	4(0.10)	0(0.00)
Vocalisation	15(0.36)	3(0.07)
Sand bathing	-	126(2.38)
Walking	460(10.94)	418(9.37)
Self-grooming	285(6.78)	330(7.40)
Floor pecking	7(2.28)	34(5.63)
Flying	-	18(0.40)

*significant differences ($P < 0.05$) between treatments by Mann-Whitney test. Statistical analysis was not performed when the number of observations for one of the treatments was zero.

Q3.2 Substrate and enrichments

When foraging and structural enrichments, and dust-baths are provided they are used extensively (29%, 26% and 16% of scans, respectively), in contrast to novel objects, and do not appear to decline in their attractiveness over the medium term (17 days) (Miller and Mench, 2005).

Quail kept on 5 different substrates: sand, dried mud, sawdust, wheat straw and rice straw, showed different behavioural responses, with no impact on a range of physical indicators including foot health, mortality and plumage condition. The authors recommend sawdust as having the greatest welfare benefit (Mohammed et al., 2017). Quail which had access to deep litter, rather than wire flooring did not demonstrate a more positive welfare state in a judgement bias task, however the authors note that there are methodological difficulties with conducting such tasks (Horvath et al., 2016).

Q4. FEAR AND DISTRESS

Several papers reported the impact of stressors on quail. A great variety of stressors were used, including loud noises, blowing air or water on the birds, shaking cages, flapping material or plastic in front of cages, modifying the home cage, feed restriction and restraint of birds (Guibert et al., 2011; Laurence et al., 2014; Favreau-Peigne et al., 2016). In all studies the stressors used were things that could occur to farmed quail, and the researchers used unpredictability as an important feature of the stressors, suggesting that more predictable negative events may be less stressful. Two studies found that the presence of a shelter (including one with an additional piece of artificial turf) appeared to ameliorate the effect of stressors (Laurence et al., 2015), an effect which continued to the next generation (Guesdon et al., 2011). Environmental enrichment in the form of hanging bottle caps, wool and plastic cylinders, as well as raised platforms were also effective at reducing the immune-suppression associated with stressful events (Nazar and Marin, 2011).

Weighing quail was found to elicit a significant adreno-cortico response when compared to control birds (Jones et al., 2005), however the response was not as great as found in other studies when the quail were transported in a crate with a stranger (Satterlee et al., 1993) or mechanically immobilised (Jones et al., 2000).

Q5. SENSORY ENVIRONMENT

Q5.1 Lighting and vision

When quail were able to adjust their photoperiod through choice of a light or dark area they showed improved liveweight gain and earlier sexual maturity, as well as a lowered heterophil/lymphocyte ratio compared to birds reared in 23h light:1h dark photoperiods, common in some commercial systems around the world (Coban et al., 2009). Unfortunately, no information was given as to the exact nature of the photoperiods that were self-selected in this study. Quail appear to show no detrimental effects on physiological or behavioural parameters of being raised in ultraviolet deficient light (Smith et al., 2005).

Q5.2 Thermal comfort

Quail may be susceptible to heat stress. The combined influence of temperature and humidity (THI) was examined by El-Tarabany (2016b) by comparing quail kept in a low THI environment (temperature 23.8 °C, relative humidity 58.5), with birds kept in a medium THI (temperature 32.8 °C, relative humidity 57.7) and birds kept in a high THI environment (temperature 35.8 °C, relative humidity 59.2). The birds in the high THI environment showed deteriorated immune response, production traits and welfare parameters in the form of raised corticosterone and heterophil/lymphocyte ratio (El-Tarabany, 2016b).

Q6. MANAGEMENT AND HANDLING

Q6.1 Stocking density

Quail kept at a high stocking density, in groups of 60-90, showed poorer fertility, productivity, immune response and welfare when housed at 143 cm²/bird compared with 200 cm²/bird (El-Tarabany, 2016a). Social contact appears very important to quail and a change to the social environment has been shown to result in greater “emotional disturbance” than a change to the physical environment (Valance et al., 2008). It may be that quail can be bred to better withstand the social stress of high stocking densities (Guzman et al., 2013) or changing social environment (Schweitzer and Arnould, 2010). Notwithstanding the ethical issues of doing so, there would likely be a variable impact on production traits of breeding strategies based on sociability or emotional reactivity traits. Recoquillay et al. (2013) found, amongst other genetic correlation results, that emotional reactivity was positively correlated with weight gain but associated with delayed egg laying onset, whereas a high level of social reinstatement behaviour was associated with earlier egg laying onset.

Q6.2 Procedures

Q6.2a Beak trimming and blunting

Using pumice for pecking can blunt the beak and reduce feather loss and injuries, and improve weight gain (Taskin and Camci, 2017). Beak trimming of quail may be undertaken in commercial systems to reduce welfare problems, however cauterising the beak to approximately 50% can reduce feed intake and weight gain in the initial rearing period (Lagana et al., 2011). Reducing the beaks of quail by 1/3 or 1/2 has been shown to have deleterious effects on egg-production measures, however birds with intact beaks have poorer feather cover: 100%, 10% and 0% back feather loss for birds with intact beaks, beaks reduced by 1/3 and by 1/2 respectively (Pizzolante et al., 2007).

Q7. WELFARE CONSIDERATIONS: OVERVIEW

Little peer-reviewed scientific literature on the welfare of actual farmed quail is available and it is recommended that such research be undertaken. Nonetheless, evidence from other studies suggest that quail welfare is greater in an ‘enriched aviary’ rather than a ‘battery cage’. Quail appear to value foraging and dust-bathing opportunities, and having opportunities to hide or access to environmental enrichments can ameliorate the effect of stressors. Quail appear susceptible to a range of stressors including visible items, noise and movement, especially if sudden and unpredictable. Quail are also susceptible to heat stress.

Quail are social birds but their welfare is compromised at high stocking densities (143 cm²/bird vs 200 cm²/bird). They can engage in injurious pecking, especially between males in a group. Offering pumice can blunt the beak thereby reducing injuries. Beak trimming is commonly employed but removing 1/3 or 1/2 of the beak, although protective for feather loss, can result in productivity reduction.

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OSTRICHES

OS1. INTRODUCTION

OS1.1 Life history

The ostrich is the only living representative of the avian family Struthionidae. It is a large African flightless bird and at least two sub-species are recognised, *Struthio camelus* and *Struthio molybdophanes*. Under natural conditions, ostriches forage in dry environments for a wide range of plant species, showing preferences for green grasses and forbs when available, and consuming leaves, flowers and fruits when preferred foodstuffs were not available (Milton et al., 1994; Miao et al., 2003). Ostriches actively select plants with high fibre content but they avoid dead or woody material.

OS1.2 Farming and rearing

Both subspecies of ostrich have been kept in captivity for meat, leather and feather production (Bonato et al., 2015). Crosses have produced different varieties and breeds (e.g. South African Black, Kenyan Red; Bonato et al., 2013). Ostrich farming began only in the mid 1800s, so farmed ostriches are considered only partially domesticated (Bonato et al., 2015). Although wild ostriches rarely exceed 100 kg, farmed ostriches can reach weights of 150 kg or more (Council of Europe, 1997; Miao et al., 2003).

Growing ostriches are described as chicks (0 to 3 months), juveniles (3 to 12 months), growers (12 to 36 months) (Mushi et al., 1998b). Wild ostriches reach sexual maturity at 4 to 5 years of age (Bonato et al., 2015) but farmed ostriches are sexually mature before the age of 3 years (Wotton and Hewitt, 1999). Ostriches are reported to have a life span of as much as 50 years in the wild (Council of Europe, 1997). Ostriches can be farmed in extensive systems (with natural or artificial incubation), semi-intensive systems (with natural or artificial incubation) or intensive systems with artificial incubation only (Shanawany and Dingle, 1999\$800\$). Extensive production has low input costs but monitoring birds and collecting eggs is difficult. For this reason, semi-intensive systems with birds kept in paddocks of approximately 8 to 20 ha are more popular. The birds obtain some food from pasture but supplemental feeding is required to meet the birds' nutritional requirements. Birds are free to choose their own mates but capture and handling of the birds can be difficult. In intensive systems birds are kept in small paddocks of 1 to 2 ha and aspects of breeding and performance can be more easily monitored and controlled. However, the costs of fencing and food provision are higher, and the birds have less opportunity to perform normal behaviour and to select their own mates and social companions.

OS2. FEED AND WATER

Milton et al. (1994) concluded that ostriches need 5-6 kg fresh mass daily, when feeding on natural forage containing 70% water, and Landau et al. (2006, full text not available) concluded that welfare was improved when ostriches were raised on pasture with a concentrate supplement, compared with a fully confined system.

Unlike chickens, and many other poultry species, the digestive system of the ostrich does not include a crop. Instead, food passes directly from the oesophagus into the glandular stomach called the proventriculus. Within this large structure, digestive secretions mix and soften the food before it is passed to the ventriculus, the specialized avian organ commonly known as the gizzard, where food is subjected to grinding and maceration. After this, food passes into the long intestine where enzymatic digestion occurs, and onwards to a large hind-gut comprising two caeca and a colon, for microbial fermentation of fibre (Miao et al., 2003). The mean retention time for small fibre particles within the digestive tract is 30-36 h, a duration that far exceeds that of the emu (Frei, 2015). From the age of about 10 weeks, ostrich chicks are able to digest cellulose and other fibre-derived substrates in the hindgut (Matsui et al., 2010). The entire system is adapted (rather like a horse) for the efficient extraction of energy from a high fibre diet.

The nutrient requirements of ostriches were reviewed by Miao et al. (2003) who reported a lack of information on many aspects such as mineral requirements. Some more recent information is available (e.g. adult female maintenance nitrogen requirement of 16.2 gN/day (100 g crude protein/day) (Bennett et al., 2012), but the literature is patchy and incomplete.

Feeding low fibre, high protein/high energy rations to encourage rapid growth has long been identified as an important contributory factor to the high incidence of leg deformities in juvenile and growing ostriches (Huchzermeyer, 2002) (see OS3.3 below) and there is now general agreement that the provision of fibre is an essential component of ostrich welfare (Miao et al., 2003). Miao et al. (2003) mention a number of potential fibre sources including lucerne, wheat bran, pasture and silage which could meet the fibre needs of ostriches. Under Australian conditions, fibre sources such as reeds or saltbush might also be considered but more information is needed on the salt tolerance of ostriches fed fibres grown in highly saline conditions.

One small scale study (18 birds in total) evaluated the effects of providing high quality roughage from alfalfa hay within pellets at concentrate:roughage ratios of 70:30, 65:35 or 60:40. The birds grew well on each of these diets. There was a trend towards lower H:L ratios in the ostriches fed the higher roughage proportions, and a significant reduction in total cholesterol and low density lipids in the blood, possibly indicating improved cardio-vascular health (Ghasemi et al., 2013). The authors recommended that ostriches should be fed the diet with the higher proportion of roughage.

Milton et al. (1993) found that ostrich chicks readily accepted supplementary termites and suggested that insect protein could be investigated further as a dietary inclusion for farmed ostriches.

The length of time that feed and water are withdrawn prior to transport is a potential welfare issue. In a recent survey of Canadian and USA producers, food was generally withheld for a few hours, but some producers withdrew feed for as long as 2 days before transport (Bejaei and Cheng, 2014a; 2014b).

OS3. RISK MANAGEMENT

OS3.1 Mortality

Mortality of ostrich chicks kept for farming purposes appears to be very high in comparison with other farmed bird species. In a prospective study of ostriches (394 chicks from 11 farms) reared in South Eastern Australia, 39% of chicks did not survive to 4 months of age (More, 1996). In India, high mortality has been reported to 3 months of age (Sivakumar et al., 2008), whilst a study of 68 chicks (Selvan et al., 2012) reported 41% mortality by 18 months. Verwoerd et al. (1999) reported that mortality can reach up to 50% to 3 months of age. Even more disturbing figures were reported by Cloete et al. (2001) in a study of 2,522 chicks reared in South Africa. In this cohort, 78.4% of chicks died before 3 months of age, with nearly half of the mortality occurring before the age of 28 days.

Samson (1997) suggested that an achievable target is that chick mortality from all post-hatching causes should not exceed 20%. The World Ostrich Association Benchmark performance targets (www.world-ostrich.org/targets.htm) suggest that overall mortality from hatch to one year of age/slaughter should not exceed 10% (and could be lower for chicks produced by older parents).

OS3.2 Causes of mortality

Chicks hatching from small eggs, or with low hatching weights, had an increased risk of death before 28 days of age (Cloete et al., 2001; Sebei and Bergaoui, 2009). Chick weight and survivability at hatch tend to increase over successive breeding seasons (Ipek and Sahan, 2004). Human intervention at the time of hatching has met with mixed results. Some studies have reported increased mortality for chicks raised by a standard artificial procedure than chicks raised by (foster) parent birds (Horbanczuk and Sales, 2000; Sebei and Bergaoui, 2009). However, the results may depend on variation in parenting ability of the adult birds, so a high level of supervision of foster parent birds would be required (Bonato et al., 2015). The nature and duration of human intervention may also play a critical role. In a study where chicks were provided with extensive gentle handling to 30 days of age (Wang et al., 2012) mortality was reduced in comparison with a standard chick rearing procedure with minimal human contact.

Ostrich chicks often show great variation in growth rate (Bunter and Cloete, 2004) and the faster growing chicks may have compromised immune function (Bonato et al., 2015).

More (1996) reported the causes of mortality in chicks and juveniles to be tibiotarsal rotation (36%), fading chick syndrome (13%) and salmonellosis (11%). In an overview provided for the OIE (the World Organisation for Animal Health), Huchzermeyer (2002) concluded that the major causes of mortality in farmed ostriches are related to rearing condition and stress, with infectious disease playing a relatively minor role. The infectious diseases that can be problematic for ostriches include Newcastle disease, which manifests in neurological symptoms such as loss of head and neck posture (but without the respiratory symptoms seen in poultry); avian influenza; upper respiratory tract disease (particularly in crowded and dusty conditions) and salmonellosis (Wieliczko and Kuczkowski, 2000; Huchzermeyer, 2002).

Enteritis is rarely reported in ostriches reared on pasture, but is one of the main causes of mortality for ostrich chicks reared indoors (Samson, 1997; Huchzermeyer, 2002). When raised on concrete, a normal intestinal microflora cannot be established, resulting in birds that are vulnerable to infection from harmful bacteria. A post-mortem study of 122 ostrich chicks, which had died from enteritis, identified *E. coli*, *Clostridium*, *Enterococcus* and *Salmonella* as the main causal organisms (Keokilwe et al., 2015). Under natural conditions, young ostrich chicks are reported to ingest parental faeces (Holtzhausen and Kotzé, 1990, cited by Christensen and Nielsen, 2004), a practice that results in the establishment of a locally-adapted intestinal microflora (Carrer et al., 2005, cited by Amado et al., 2011). Cold and wet conditions and the use of antibiotics are additional risk factors. The use of probiotics has been suggested as a preventive measure (Samson, 1997) but no controlled scientific studies on this matter could be found.

OS3.3 Bone strength, bone damage, deformities and lameness

As with other fast-growing farmed birds, such as broiler chickens and turkeys, problems with bone composition and skeletal function have been identified. Although a newer industry, many of the trends that have resulted in welfare problems for broiler chickens are now observed in those ostriches selected for meat production. Genetic selection for faster growth rates, higher body mass, and greatly increased muscle development is now associated with disturbances in bone growth and with deformities and fractures. The skeletons of these ostriches appear to be insufficiently adapted to cope with the increased mass of the birds (Tatara et al., 2016). Samson (1997) identified rapid growth rates (bodyweight >4.5 kg at 28 days of age) with little opportunity for exercise as a risk factor for skeletal defects.

Currently, there appears to be a great deal of variation between ostriches in the structure, density and mechanical properties of their long bones (Tatara et al., 2016) suggesting that there may be potential to use birds with the better bone traits in breeding programmes, thereby avoiding some of the worst problems seen in other farmed bird species.

The long bones of the tibia and tarso metatarsus are the most likely to be affected. Morphological defects are thought to contribute to further problems, including bone rotation (Charuta et al., 2013). This is especially serious as the whole body mass of the ostrich rests on the tibia. Rotation reduces stride length and running speed (Cooper, 2007). In severe cases tibiotarsal rotation is a significant cause of death, with peak onset between 2 to 10 weeks of age, and a median survival time of just 10 days after diagnosis (More, 1996). Less commonly, bowing of the leg bones has been observed. This condition appears to be associated with a pathological and progressive disease state which slows growth of the metatarsal bone (Cooper et al., 2008). The chest wall can also become skewed in association with tibiotarsal rotation (Samson, 1997).

No single cause of these leg pathologies has been identified. Mineral balance may play a role, and calcium and phosphorus levels in the bones have been reported to be lower in affected than healthy birds (Huchzermeyer, 1998, cited by Huchzermeyer, 2002). Supplementation of water with 200 mg/l of boron increased the length, weight and ash content of ostrich chick bones, but not the bone mineral density (Cheng et al., 2011). The role of a low fibre, high protein diet is a more plausible causal factor, with high growth rates resulting in osteodystrophy and rapid soft tissue development. Lack of exercise in a confined environment is also a likely contributing factor (Miao et al., 2003). It has also been suggested (Huchzermeyer, 2002) that rotation is related to chicks stumbling over obstacles in their environment (though cause and effect would seem to be difficult to disentangle in this case).

Under Australian conditions, tibiotarsal rotation was reported to affect just over 10% of ostrich chicks in a study of 31 farms (Squire and More, 1998, full text not available). In Botswana, limb deformities were detected in 15.3% of ostrich chicks, with 73% of the affected chicks suffering from tibiotarsal rotation, and 36% from rolled toes (Mushi et al., 1999). Aslan et al. (2009a) reported a variety of lower limb deformities that affected 35.8% of ostrich chicks. Of these, approximately half were considered congenital, including leg and toe deviations and rotations, and half were acquired, including tarsal joint arthritis, fractures, dislocations and other injuries. Bandaging treatments were applied to many of the cases, with a reasonable success rate (66%) reported (Aslan et al., 2009a). However, it should be noted that no control groups were employed to monitor whether any spontaneous improvement occurred in non-bandaged animals. Surgical treatment is reportedly ineffective as well as expensive (Stewart, 1994, cited by Samson, 1997).

OS3.4 Stomach impaction

Growing ostrich chicks have a tendency to ingest a variety of non-food materials in their environment, including sand, stones, and foreign materials such as plastic bags or metal objects such as bottle tops (Samson, 1997; Mushi et al., 1998b; Komnenou et al., 2003; Sen and Albay, 2003). This is one cause of impaction of the proventriculus and/or the gizzard. One obvious preventive step is to ensure that foreign objects e.g. plastic or metal, are cleared from ostrich enclosures.

However, impaction can also result when birds ingest normal forage materials (Samson, 1997). Impaction can result in inflammation of the proventriculus and gizzard, weight loss, lethargy and death. Impaction has been reported in birds aged between 3 and 24 months (Gulbahar et al., 2000; Yuksek et al., 2001) and in adult birds (Samson, 1996), but appears to be most common in juvenile birds (Samson, 1997; Mushi et al., 1998b). On one farm in Turkey 14 cases of impaction were recorded from just 25 birds over the course of a year (Yuksek et al., 2001). Of these half recovered following treatment and half died. Death can also occur very rapidly, without obvious preceding clinical signs (Mushi et al., 1998b). The risk of impaction appears to increase with stress and confinement (Samson, 1997).

Another preventative step is to provide *ad libitum* food to reduce bird motivation for ingestion of other materials (Mushi et al., 1998b). It is more difficult to manage the over-ingestion of sand, soil or stones (see OS4.2).

Suggested treatments include the administration of lubricants and surgical intervention via proventriculotomy (e.g. Honnas et al., 1993; Komnenou et al., 1993; Aslan et al., 2009b). However, the efficacy of these approaches is not clear, despite case reports of apparent success rates. No case-control studies appear to be available and sample sizes and individual farm or surgery level factors are too idiosyncratic to draw overall conclusions. It appears from some reports that there can

be a relatively high risk of peri-operative death due to the weakened condition of birds at time of surgery (Honnas et al., 1993). Surgery will also pose risks to welfare including stress, infection and uncertain longer-term prognosis.

Young ostrich chicks sometimes fail to grow and thrive, with resultant high mortality before 6 weeks of age. This so-called 'fading chick' syndrome is poorly understood but it bears some similarities to the reports of gastric impaction above. Post-mortem results from faded chicks have shown that food is present in the proventriculus but has not been passed onwards to the intestine (Huchzermeyer, 2002).

OS3.5 Feather pecking and other abnormal forms of pecking

Feather pecking, and other forms of abnormal pecking such as toe pecking, face pecking, repetitive object and air pecking, occur in young and adult ostriches (Lambert et al., 1995; Samson, 1997; Csermely et al., 2007) and are reportedly associated with confinement, stress, low duration of time spent feeding and diets that differ markedly from those in the wild (Sambras, 1995, cited by Miao et al., 2003 and by Christensen and Nielsen, 2004; Samson, 1996). As in laying hens, abnormal pecking may result when opportunities to perform normal feeding, foraging or exploratory pecking behaviours are absent or insufficient. In ostrich chicks, individuals that direct toe or face pecking towards their companions appear less healthy and have higher mortality than other chicks (Lambert et al., 1995). In adult ostriches confined indoors during cold Canadian winters, a wide variety of abnormal pecking behaviours have been observed, including feather pecking, toe pecking and face pecking (Samson, 1996). Reischl and Sambras (2003) studied feather pecking in farmed ostriches in Israel and noted feather pecking in 5.8% of the 11,145 birds observed. Up to the age of 18 months all birds were observed to perform some feather pecking, but after this age less than 40% of birds engaged in this behaviour. Highly repetitive abnormal behaviour may be a sign of poor welfare of the initiating ostrich (independently of damage caused to any victims) (Christensen and Nielsen, 2004). However, confirmation requires secondary strands of evidence (Mason and Latham, 2004). The poor health of chicks that engage in these behaviours (Lambert et al., 1995) provides some support for this interpretation.

OS3.6 Parasitic infections

Ostriches can become infested with quill mites (*Gabucinia bicaudata*) and lice (*Struthiolipenrus struthionis*) causing skin and plumage damage and irritation (Cooper and El Doumani, 2006).

No coccidia or stomach worm infections were detected in ostriches kept under Australian conditions, with only trace detection of other nematode infection (More, 1996). However, in Botswana, coccidian oocysts were found in faecal samples of 34% of 156 young farmed ostrich chicks, but these infections did not appear to cause welfare or production problems. Oocysts were not detected in young ostriches over the age of 9 weeks (Mushi et al., 1998a).

Ostriches can be infected with the stomach worm, *Libyostrongylus douglasii*, which lives just beneath the surface layer of the proventriculus and gizzard. Infection can result in irritation, disruption and damage to the stomach surfaces, with severe cases resulting in gastric stasis, anaemia and a slow death. Conventional worming treatments are largely effective against this parasite (de Souza et al., 2012).

OS4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

OS4.1 Behavioural time budget

A first step in establishing behavioural needs is often to compare the behaviour and time budgets of captive animals with that of their wild or feral counterparts (e.g. Weeks and Nicol, 2006). There is some information on the behaviour of wild ostriches and the time budgets of captive ostriches presented below. Further information on whether different activities can be considered behavioural priorities or needs within a captive environment (e.g. from preference or demand tests, or on physiological consequences of deprivation) is not available for ostriches.

Ostrich chicks live on the reserves from the yolk sac for a few days after hatching. They start to peck and forage at around 4-5 days of age (Christensen and Nielsen, 2004). Under natural conditions ostriches can travel great distances in search of sparsely located food and water. Ostriches living within the Namib desert have been reported to spend 7.5 h/day walking (Williams et al., 1993). Bertram (1980) reported that the percentage of the day spent in foraging behaviour varied between 65 and 85%, depending on group size.

Bubier et al. (1996) found that ostrich chicks (to 14 days) spent 50.7% of their time foraging (walking and ground pecking). A more detailed time budget study was conducted by Amado et al. (2011) who grouped chicks according to age, with 30 individuals in each age-group (10-40, 41-60, 61-90, 91-120, 121-150 days). Younger birds (to 60 days) were housed in 20x20 m paddocks with older groups in larger enclosures. The ostriches received concentrate, alfalfa and *ad libitum* water. The youngest birds (10-40 days) were highly active, spending less time standing than birds in the other age groups and more time running and walking. Locomotor play (dancing) was observed in the youngest birds only (Amado et al., 2011). The youngest birds also ingested faeces (coprophagia), but were not observed in other pecking activities or in the ingestion of stones or gravel. For ostriches aged over 40 days, the ingestion of small stones was a common activity,

occurring between 2 and 3 times per bird, per hour. Dust-bathing also occurred in ostriches over 40 days of age, although relatively infrequently at about 0.1 times per bird, per hour.

Other studies of ostrich time-budgets are summarised in Table OS1. Generally, all studies highlight locomotor activity (walking and running) and pecking at the ground or environment (a component of foraging) as the activities that dominate during daylight hours. Male and female time budgets are generally similar (McKeegan and Deeming, 1997; Csermely et al., 2007) apart from increased territorial pacing observed in some paired male birds. A notable feature is the increased resting and reduced pacing and locomotion of birds kept in large groups in larger enclosures, which may possibly be due to a reduced need for vigilance (McKeegan and Deeming, 1997) and potentially reduced fearfulness.

Table OS1: Daylight behavioural time budgets (%) recorded in studies of juvenile and adult ostriches

Study	Sit/crouch/rest	Walk/pace	Stand	Eat	Peck/forage
Degen et al., 1989 5-6 month juveniles	20.3	61.5	5.5	6.6	5.0
Meyer et al., 2003 9-13 month growers					13 - 15
McKeegan & Deeming, 1997 Adult paired males	7	36	27	8	12
McKeegan & Deeming, 1997 Adult paired females	8	16	21	4	27
McKeegan & Deeming, 1997 Adult males (large group)	27	7	26	4	23
McKeegan & Deeming, 1997 Adult females (large group)	42	4	20	4	24
Ross and Deeming, 1998 Adult female	6.0	2.3	15.9	19.9	25.7
Csermely et al., 2007 Adult paired males	7.7	44.0	17.5	9.6	42.1
Csermely et al., 2007 Adult paired females	6.0	40.4	16.6	12.7	45.1
In some studies percentages are less than 100% because a wide variety of "other" activities were observed, each at a low duration. In the study by Csermely et al. (2007) percentages are more than 100% suggesting the behaviours recorded were not mutually exclusive (e.g. bird could be both standing and pecking).					

OS4.2 Foraging and ingestion

Ostriches, more than some other types of birds, need to ingest small stones to enable proper maceration of food within the gizzard. Under natural conditions, in a varied environment, parental guidance is available to assist young chicks learn the identity and size of appropriate food and grit particles for ingestion. It is reported that chicks mimic the food selection of their parents (Carrer, 2004, cited by Amado et al., 2011). However, in captive ostriches this balanced system can go awry as chicks are not taught what to ingest. The tendency of young ostriches to ingest inedible materials has been considered by some to be a behavioural problem associated with stress or an inadequate environment. It has been described as "aimless eating" (Mushi et al., 1998b) and can result in overfilling of the stomach and impaction (as described in OS3.4).

It is therefore something of a challenge to provide an environment that allows ostrich chicks to perform normal foraging and exploratory behaviour whilst avoiding injury or damage. Christensen and Nielsen (2004) attempted to tackle this challenge by comparing the behaviour of 40 chicks (2 groups) raised with an indoor hut and a barren outdoor sand arena, with that of 40 "enriched" chicks (2 groups) provided with additional cabbage, conifer cones, and sticks. The enriched chicks pecked at and consumed approximately 26 g cabbage/chick/day, they pecked less at inanimate objects, spent more time outside and were more likely to approach a novel forage type than control chicks. The authors concluded that

the appropriate provision of resources to encourage foraging improved chick welfare without reducing concentrate food consumption. Bodyweight and growth were not monitored in this study.

OS4.3 Sleep

Ostriches are diurnal and are reported to sleep for approximately 11 h/day. In most birds and mammals periods of slow wave and REM (rapid eye movement) sleep occur in distinct and separate bouts. However, ostriches (and monotreme mammals such as the platypus) show less segregated patterns of brain activity, suggesting a possible difference in the function of sleep in these more "basal" birds and mammals (Lesku et al., 2011). There may be implications of this unusual avian sleep pattern for ostrich welfare (in terms of photoperiod or other lighting conditions) but we could find no studies on this matter.

OS4.4 Reproductive behaviour

In the wild, both male and female ostriches have multiple partners. Reproduction in farmed ostriches is linked to changes in seasonal photoperiod, with a breeding season that starts in the spring and lasts for 5 to 8 months (Bonato et al., 2015). Under farming conditions, many breeding ostriches are kept for reproductive purposes only, their eggs being removed for artificial incubation (Csermely et al., 2007).

Under natural conditions, ostriches have a unique communal nesting system, where many females lay eggs in the same nest (Bonato et al., 2015). The territorial male prepares many scrapes in the ground, of which one becomes a nest where females lay their eggs (Bertram 1992; Kimwele and Graves 2003). Sebei et al. (2009) found that ostriches in semi-wild enclosures tended to dig their scrape nests adjacent to the reserve enclosure, subjecting them to human disturbance and predation. In the Serengeti, nests containing up to 38 eggs have been recorded (Magige et al., 2009) but often only one (major) female and one major male incubate the eggs (Bonato et al., 2015). The major female may selectively evict the eggs of other hens after a certain threshold number has been laid in the nest (Bertram, 1979), although the cues used to discriminate between eggs are not yet clear (Magige et al., 2010). Sometimes a second female can assist in egg incubation (Sebei and Bergaoui, 2009). The presence of eggs in the nest stimulates incubation and reduces mating and laying activities (Sebei and Bergaoui, 2009). After hatching, the major female and major male will guard the large crèche of chicks. Under farmed conditions, where breeding pairs also incubate eggs, a skew in reproductive effort is also observed, with specific combinations of male and female pairs producing disproportionately far more chicks than other pairs (Bonato, 2009, cited by Bonato et al., 2015).

OS5. FACILITIES AND EQUIPMENT: BEHAVIOURAL USAGE

Information on the facilities and equipment used to rear and house ostriches is sparse. In cold climates, adult ostriches may be confined indoors during winter, and ostrich chicks will be reared in indoor pens that provide a relatively barren environment compared with the natural environments in which ostriches are found (Samson, 1996; Christensen and Nielsen, 2004). Confinement has been discussed above as a risk factor for disease, skeletal pathology and abnormal pecking (section OS3). Aggression is also reported to increase during periods of confinement (Samson, 1996).

OS6. FEAR AND DISTRESS

Bubier et al. (1998) reported that aggression towards humans was reduced if young ostriches had imprinted on (or at least become habituated and familiarised with) people during their early life. Studies to examine such claims have more recently been conducted. For example, Bonato et al. (2013) compared ostrich chicks that had been raised by a standard rearing practice with minimal human contact (Standard), chicks raised using breeder pairs as foster parents with minimal human contact (Foster), chicks raised using standard chick rearing practices with extensive human presence and care to 30 days of age (Imprint 1) and chicks raised with slightly reduced human presence and care (Imprint 2). There were few differences between Foster and Standard groups, but chicks raised with human care were more likely to interact with humans and allow human touch. Imprint 1 chicks maintained a closer distance to human observers but no differences between groups were detected in aggressive, hissing or pecking behaviours. The authors suggest that the early life handling alleviated fearfulness.

It has been suggested that the provision of a clothed dummy for young ostrich chicks might reduce fearfulness (Mushi et al., 1998b). No scientific data could be found to support or refute this suggestion.

OS7. SENSORY ENVIRONMENT

OS7.1 Thermal comfort

The evolved environment of the ostrich is warm (or hot) and dry, and these birds are well-adapted to cope with these conditions, showing effective thermoregulation in temperatures of over 40 °C (Schrader et al., 2009). However, it has been suggested that welfare problems may arise if the birds are kept in cold or damp conditions to which they are less adapted. Ostrich feathers have a soft structure and, unlike chickens for example, ostriches have no uropygial gland to produce oil that can be spread onto the feathers during preening for waterproofing and protection (Maloney, 2008). On the other hand, ostriches may be able to adapt to the cold by increasing feed intake, changing posture (e.g. covering naked parts of skin with wings, huddling), and in the longer-term by laying down fat reserves (Maloney, 2008). Schrader et al. (2009) studied ostriches with implanted digital temperature loggers, on a German farm during the cold (but dry) winter months (mean ambient temperature 2.5 °C). The mean body temperature of the ostriches varied between 37.2 and 38.5 °C, lower than measured in ostriches in warmer environments, probably due to the lower external temperature. However, differences in age, calibration and position of data loggers cannot be excluded as influencing factors. High variation between and within individuals in body temperature was noted but the authors concluded that there was no evidence that the birds had failed to cope with the cold. Evidence about the ability of birds to cope with wet conditions was not found.

OS8. MANAGEMENT AND HANDLING

OS8.1 Stocking density

It is difficult to establish information on stocking density or stocking rate. This information is not always provided even in otherwise thorough scientific papers (e.g. Meyer et al., 2003) or is unclear or contradictory (e.g. Amado et al., 2011). Some papers mention stocking rates, e.g. Lambrechts et al. (2004, full text not available) reported 'intensive' stocking rates of between 114 to 210 birds/ha in large flocks, and between 9 and 13 birds in 0.13 and 0.30 ha enclosures; Amado et al. (2011) report that groups of 30 chicks were kept in 400 m² paddocks. No controlled studies on the effects of different stocking rates or stocking densities on ostrich health or welfare were found.

In Europe group sizes and stocking rates are advised by Council of Europe (CoE) guidelines. These advise that ostriches from 3 days should be given opportunities to exercise, ideally outdoors, and that ostriches over 3 months should be given some daily access to an outdoor area (COE, 1997). Fences must be safely constructed and at least 2 m high. Buildings should be 3 m high and birds should have a minimum indoor space allowance of 2 m²/bird from 3 weeks, and of 10 m²/bird from 6 months, and a minimum outdoor area of 800 m²/3 birds from 6 months, of 1,000 m²/3 birds from 1 year and of 2,000 m²/3 birds for breeding adults. However, these guidelines appear to have been drawn up from 'best practice' information rather than scientific studies.

OS8.2 Breeding group size and sex ratio

Ostrich breeders use two main methods for mating adults. Birds are generally either kept in breeding groups of 6 females and 4 males, or maintained in much larger 'camps' of approximately the same sex ratio (Bonato et al., 2015), with only a few instances of single pairs of individuals kept for mating (e.g. Csermely et al., 2007). It has been suggested by some that the restriction of mate choice compared to the natural situation could pose a welfare problem (Bonato et al., 2015). Ostriches housed in small enclosures with incompatible mates may experience aggression and injury (Cloete and Malecki, 2011). Bonato et al. (2015) suggested that breeding animals should be kept in small colonies of fewer than 20 individuals (but more than 3 or 4 individuals), to allow normal sexual behaviour whilst maintaining a social structure.

In breeding adults, male to female ratios of 1M:1F; 1M:2F and 1M:3F were studied in small 0.06 ha enclosures. In all systems, egg production, fertility and hatchability were reduced as stocking rate increased. However, increasing the number of females per male was generally beneficial (Lambrechts et al., 2004, full text not available).

OS8.3 Chick groups

Chicks reared in mixed body-weight groups have reduced average growth rates compared with chicks raised in groups of similar bodyweight (Deeming and Ayres, 1994). Meyer et al. (2003) investigated the possible benefits of single-sex rearing of ostrich chicks and juveniles to establish whether this would reduce aggression and skin damage. Behavioural observations showed greater aggression in all-male groups, with more kick marks on the skin, than in the female or mixed groups. Overall, however, the contribution of aggression to final skin grading was not clear and it was concluded that there was no overall benefit to single-sex rearing.

OS8.4 Handling

OS8.4a Bird movement, restraint and penning

In a review of ostrich handling and transport practices, Reiner et al. (1996, cited by Wotton and Hewitt, 1999) suggested it was easier to handle ostriches as a group than as individuals, and that these birds remained calmer if kept in familiar groups. Wotton and Hewitt (1999) also suggested that young ostriches have a strong flocking instinct, citing a personal observation that flocks of young birds could run into fences if alarmed. Wotton and Hewitt (1999) did, however, suggest that the flocking tendency could be harnessed to good effect; if, for example, a lead bird can be enticed into a trailer or raceway, the other members of its group may follow.

Young ostriches up to 2 months of age can reportedly be picked up if the chest and back are supported and held and the legs allowed to dangle (Sales and Smith, 1995, cited by Wotton and Hewitt, 1999). Older ostriches must be handled with care, not only to safeguard their own welfare, but also because they can kick or otherwise injure humans during manual handling or restraint (Wotton and Hewitt, 1999). Minka and Ayo (2008) observed the effects of handling procedures that occurred prior to loading and transportation, in 20 groups (250 individuals) of adult ostriches. The procedure involved herding the birds into a holding pen, then moving them individually into a V-shaped crush and placing a hood over their heads. It was stated that procedures were conducted in accordance with UK guidance on the welfare of animals during transport. Pronounced behavioural responses occurred during this procedure, with mean frequencies of falling (60%), slipping (85%), aggression (60%), jumping (35%) and kicking (20%) and consequent injuries to the legs (60%), neck (15%) and wings (10%). The frequency of these responses and injuries was far higher during the handling procedure than during subsequent loading, transport and unloading.

It may be possible to gently guide some birds to a desired position but this will be easier if the birds have been habituated to handling from an early age (Wotton and Hewitt, 1999). In a survey of ostrich handling practices in the USA and Canada, approximately half of 39 respondents used hooding as a restraint method, 25% did not use any devices, 5% used a hook, 5% used tranquilisers and 15% used other methods such as livestock handling units for bird restraint (Bejaei and Cheng, 2014a). Most of the producers in this survey kept ostriches in a pre-transport holding pen for between 1 to 18 h before loading for transportation, generally grouping the birds according to weight but not previous social familiarity or sex. Producers identified fearfulness (26%), running (16%), vocalisation (13%), kicking (9%), birds piling on top of each other (10%), trampling (6%) as behavioural changes observed during pre-transport handling procedures. 3% of producers also mentioned that birds ceased feeding and drinking.

The authors concluded that handling injuries, bruises and losses are common, and that there is a need for research to evaluate the effects of the different methods of handling on bird welfare, and argued that producers should consider the social familiarity and sex of the birds when mixing them during handling. It is likely from work on other bird species (see Laying Hens) that mixing unfamiliar birds is stressful. However, studies in ostriches have confounded transportation and translocation with mixing (Kamau et al., 2002) and so the relative contribution of mixing alone to increased stress response is not clear.

Juvenile ostriches can be sedated using intra-nasal administration (Araghi et al., 2016), although it should be noted that the CoE guidance does not permit routine chemical restraint due to the risks of injury during recovery.

OS8.4b Artificial reproduction

Natural mating is the normal practice in ostrich farming but there is some interest in developing artificial insemination to improve genetic stock (Rybnik et al., 2007). Handling birds for the collection of semen and for the insemination process is likely to pose welfare challenges. Four different methods of semen collection were assessed by Rozenboim et al. (2003) who concluded that a vacuum method was an effective and restraint-free method that appeared to be low stress. Any technique for semen collection or insemination will rely heavily on the docility and cooperation of birds with human handlers, so alleviating fear and aggression will be critical for bird welfare and human safety.

OS8.5 Declawing

Declawing is a procedure that is not permitted in some countries, but which may be practiced on “some” Australian ostrich farms (Glatz, 2006). It involves partial amputation of the toe, specifically removal of the distal phalangeal joint using a hot-blade device designed for beak trimming (Glatz, 2006). Others have described a manual procedure using a scalpel to make a diagonal cut from underneath the toenails upwards to remove the growth point and the toenail, whilst keeping the ventral foot pad intact (Meyer et al., 2002). Declawing is effective in reducing scratches and skin marks that can reduce the ultimate quality of ostrich leather (Meyer et al., 2002; Glatz, 2006) but it has the potential to result in a significant degree of short-term pain, with the possibility of longer-term adverse consequences for bird welfare. We have been cautious in extrapolating across species but the toe region of chickens and ratites is supplied with numerous blood vessels and nerves (Gentle and Hunter, 1998; Lunam and Glatz, 2000) and despite the absence of studies on ratite species, their brains have a similar structure to the chicken brain, suggesting a capacity to experience pain in association with tissue damage.

Meyer et al. (2002) compared approximately 140 day-old de-clawed chicks with a similar number of controls. Ostriches struggled during the declawing procedure, but the wounds reportedly healed well. Survival to slaughter was very low, just 33% in the control group and 25% in the declawed group. The cumulative proportion of chick deaths between 85 and 135 days was significantly lower in the declawed group. At 13 months of age no impairment in locomotion was detected and the declawed birds had a reduced level of skin damage at slaughter. The authors concluded that welfare was unaffected by declawing but this is not a robust conclusion given the lack of evidence obtained at the time the procedure was conducted. A more measured conclusion might be that there was no evidence of a long-term detriment to welfare. Assessments taken at and shortly after the declawing procedure by Glatz (2006) revealed that some hours after the procedure declawed chicks showed that, whilst there were no differences between declawed and control chicks in some activities (feeding, drinking, walking, preening), significant reductions in other activities were observed (sitting, standing, environmental pecking and display (kantelling) behaviour). This was interpreted as an indication that the chicks may have been suffering pain and discomfort (Glatz, 2006). One week after the procedure, fewer behavioural differences were observed, but declawed birds behaved differently in the outdoor runs performing more walking, but also more sitting and standing, results that are difficult to interpret clearly. At one year of age, the declawed birds were significantly more likely to slip (Glatz, 2006).

OS8.6 Feather removal

The CoE advises that feathers should not be plucked from live birds, and that if any feathers are to be collected from live birds this should be done by feather clipping above the blood line. The practices adopted to collect feathers in other countries are not clear. In South Africa, live birds may have (an unspecified number of) their feathers 'harvested' during the winter non-breeding period (Brand and Cloete, 2015). Plucking feathers from live birds would be likely to cause pain but no scientific studies of the welfare impact of this practice were found.

OS9. WELFARE CONSIDERATIONS: OVERVIEW

The feeding behaviour of the ostrich, and the anatomy and physiology of its digestive tract, enables the consumption of a varied, and highly fibrous, plant-based diet. Under farming conditions ostriches will readily accept low fibre diets with high energy and/or protein content, but such diets result in significant welfare problems both because the motivation to forage is directed towards more harmful substrates (e.g. feathers, skin, or objects that are harmful when ingested) and because resultant rapid growth rates can cause musculo-skeletal problems and leg deformities. Diets should be provided that enable healthy, but not excessive growth rates.

Mortality rates in ostrich production, particularly of young chicks and growing birds, are very high in comparison with other farmed bird species. This suggests that considerable research into improved hatching and rearing practices is still required. Skeletal problems and enteritis are both major causes of early mortality and both will result in welfare problems before death. Genetic selection for high growth rates needs to be balanced against a consideration of the welfare impact and economic losses associated with musculo-skeletal disorders. Targets for 'acceptable' mortality rates should be set and monitored.

Research is needed to establish optimum strategies to enable foraging (a major component of the natural ostrich time-budget) and ingestion of beneficial fibrous material to promote gut health and prevent injurious pecking in both growing and adult ostriches, and should be implemented both for ostriches with access to the outdoors and during any periods of indoor confinement.

Ostriches are not fully-domesticated birds and they can be fearful and aggressive in the presence of human handlers. This can reduce their welfare directly (fear is a negatively-valenced emotion) and indirectly (via injury caused by panic). Positive strategies for the early handling of chicks may help to reduce fearfulness and aggression. Many different handling methods have been reported for older birds but research is needed to establish their relative effectiveness and welfare impact.

There is a lack of scientific work on the impact of different stocking rates, group sizes and group compositions on ostrich welfare. This is an important area for future research to support recommendations for ostrich farming.

De-clawing is a practice that is permitted primarily to reduce skin damage and improve the quality of ostrich leather products (it may also reduce the risk of injury to human handlers). From a welfare perspective de-clawing is a major and substantial concern. Given the high innervation of the toe region, the removal of toes with a hot blade without analgesic or anaesthetic provision, is likely to cause severe pain, at least over the short-term. Research should be conducted on strategies to reduce skin damage in other ways (e.g. by ensuring stable and compatible groups of birds, ensuring low competition for resources, providing areas of abrasive flooring to blunt claws naturally) and on improved handling practices so that de-clawing is no longer (as in some other countries) deemed a necessary practice.

OS10. REFERENCES

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EMUS

EM1. INTRODUCTION

EM1.1 Life history

The emu is a native Australian flightless bird, within the same subclass of birds as the ostrich, but belonging in a separate family (with the cassowaries). Its range covers most of Australia.

EM1.2 Farming and rearing

Commercial emu farming in Australia started in the 1970s. Emu are farmed for meat, decorative eggs and there is increasing interest in emu oil for medicinal or cosmetic purposes.

EM2. FEED AND WATER

Nutritional deficiency of vitamins E and A has been recorded as the most likely cause of a suite of pathological findings in embryonic and day-old emu chicks from a farm with a poor hatching and post-natal survival record (Crispo et al., 2016). The pathological findings included widespread subcutaneous swelling and haemorrhage, liver haemorrhage, muscle necrosis and eye defects. After diet was changed to one which met suggested levels for emu chicks (vitamin E 99 IU/kg; vitamin A 15,432 IU/kg) and breeders (vitamin E 99 IU/kg; vitamin A 8,818 IU/kg) hatching and survival rates were reportedly improved.

Emus drink infrequently but can ingest large amounts when water is available.

EM3. RISK MANAGEMENT

EM3.1 Mortality

Embryonic loss before hatching is reported to be high with hatching rates varying from 36% to 73%, and high (but unspecified) neonatal mortality (Tully and Shane, 1996, cited by Crispo et al., 2016).

EM3.2 Causes of mortality

The infectious condition erysipelas can be a cause of mortality in otherwise healthy farmed emus of approximately 10-12 months, particularly during cold and wet ambient conditions (Swan and Lindsey, 1998). The risk of this condition may be reduced by keeping a low stocking density and even distribution of feeding and watering points to avoid birds clustering in one area (Griffiths and Buller, 1991, cited by Swan and Lindsey, 1998).

EM3.3 Parasitic Infections

Internal parasites reported in Australian farmed emus include the liver fluke (Vaughan et al., 1997), and lungworm (Rickard et al., 1997).

EM4. FACILITIES AND EQUIPMENT: BEHAVIOURAL NEEDS

A high degree of individual variation in drinking behaviour of captive emus in Western Australia has been recorded under laboratory conditions, with the quantity of water consumed positively correlated with ambient temperature (Davies and Knight, 2016, full text not available). In hot weather (>30 °C) emus were observed to spend more time sitting and pacing, and less time grooming, feeding and drinking than under cooler conditions (Glatz, 2001).

Under natural conditions emus adopt a variety of reproductive strategies including monogamy, polyandry and promiscuity (Coddington and Cockburn, 1995).

EM5. SENSORY ENVIRONMENT

EM5.1 Thermal comfort

Emus are found in cold mountainous regions and within the arid interior of Australia. Maloney and Dawson (1994) found that emus maintain a constant body temperature within environments ranging from -5 to 45 °C. At low temperatures, emus

sit down to reduce heat loss, whilst at high temperatures they pant and lose water through the skin to keep cool. If emus are deprived of water for more than 2 weeks then there is a later onset of panting, and lower evaporative water loss. At high ambient temperatures this produces a consequent rise in body temperature (Maloney and Dawson, 1998).

EM6. MANAGEMENT AND HANDLING

EM6.1 Declawing

In Australia emus are sometimes declawed using similar methods as employed for ostriches (see OS8.5). A histological examination of emu toes revealed the presences of numerous blood vessels, nerve bundles and pressure receptors (Lunam and Glatz, 2000). One study compared the behaviour of 40 emus that had been declawed as chicks with a control group of 40 emus (Glatz, 2001). However, observations were not taken at, or soon after, the time of declawing, so information on the painfulness of the procedure is simply not available. At one year of age there was no evidence of limping, or of neuroma formation which could indicate ongoing chronic pain. Declawed emus performed less pacing behaviour but more searching behaviour (Glatz, 2001).

EM7. WELFARE CONSIDERATIONS: OVERVIEW

There is very little peer-reviewed scientific work on emu welfare. Basic information on the mortality rates or the prevalence of different diseases or welfare problems is lacking and it would be useful if such research could be conducted under Australian conditions.

The natural diet of the emu is highly varied, comprising both plant and insect material. Based on evidence from related farmed bird species, welfare problems may arise if emus are provided with low fibre diets designed to encourage rapid growth but direct evidence for effects of diet on welfare in this species is lacking.

Emus are not domesticated birds and so careful rearing and handling practices need to be devised to minimise fear and the risk of injury to birds and handlers.

As for ostriches, de-clawing may be practiced to reduce skin damage and reduce risk of injury to human handlers. The comments given for ostriches on the welfare impact of this practice apply also to the emu. In addition, unlike for the ostrich, the effect of de-clawing on skin damage does not appear to have been quantified (at least in the scientific literature) and so it is not possible to assess the balance of harm against benefit.

EM8. REFERENCES

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SLAUGHTER

SL1. INTRODUCTION

Large numbers of farmed birds are reared for meat production. Slaughter is a vital part of this farming process. At slaughter, there is significant potential to compromise welfare through stress, pain and suffering. This can be minimised by the use of appropriate slaughter methods and equipment, staff training and the development and use of Standard Operating Procedures (EUWeNet, 2014).

Humane killing of birds is also necessary due to disease or injury of individuals, disease in a whole flock, where there has been surplus production (e.g. day old chicks), or where the birds have come to the end of their economic value (laying hens). In these circumstances there are significant welfare advantages if the killing takes place on the farm since this minimises handling and transport stress and the risk of the spreading any disease. Methods for on-farm killing often differ from abattoir-based slaughter methods however the principles of ensuring immediate or stress free loss of consciousness without recovery should be maintained. In all cases, slaughter and humane killing should be carried out by trained personnel, using appropriate equipment and with established welfare monitoring protocols.

The amount of peer-reviewed scientific literature covering this field varies by species. For some species, welfare at slaughter is well researched but for others there is very little published information. This review focuses on peer-reviewed literature however there is a literature comprising conference proceedings, student research dissertations and advice published by the industry and by animal welfare organisations that may provide further information. A good example of such information is publications by the Humane Slaughter Association (www.hsa.org.uk).

The first section of this review covers the main slaughter methods. This literature is dominated by broiler research. The second section of this review focuses on research results specific to each bird type or species.

SL2. OVERVIEW OF SLAUGHTER AND HUMANE KILLING METHODS

SL2.1 Stunning and killing

The process of slaughtering an animal will normally have two parts. The first is the stun, which means any intentionally induced process which causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death. The second is to ensure that the animal dies before consciousness returns. The stun should result in prolonged unconsciousness for most animals so that any mistakes, malfunctions or delays in applying the second step do not result in injured animals recovering.

For controlled atmosphere stunning and low atmospheric pressure stunning, death is achieved by a prolonged and more intensive application of the gas or low pressure that was used to stun. However for mechanical percussion and electrical stunning, death cannot be guaranteed so a second, separate, killing action is needed. For animals killed for meat this will be achieved through bleeding but in other cases cervical dislocation may be appropriate.

SL2.1a Bleeding

Poultry bleeding is most effectively achieved with a complete ventral neck cut, severing both carotid arteries, while the bird is inverted. This ensures brain death through cerebral ischemia. Raj et al. (2006a; 2006c) demonstrated that for chickens stunned with an alternating (AC) or pulsed direct (pDC) current over a range of frequencies, the electroencephalogram (EEG) declines to less than 10% of normal levels within 20 s of a ventral neck cut, but when neck cutting is unilateral, this time can exceed one minute. Other studies have also shown that when all the major blood vessels in the necks of electrically stunned chickens are cut, blood loss accounting for 2% body weight occurs within 25 s. This, it is speculated, will result in cerebral ischemia and death (Gregory and Wilkins, 1989a).

Although decapitation is shown to lead to rapid brain death, it is an option that needs to be used with caution because it provides fewer opportunities to observe the birds following stunning so the behavioural indicators of a poor stun are less likely to be observed and rectified. However, when decapitation is followed by immediate maceration of the head, bird welfare is protected.

SL2.1b Cervical (neck) dislocation

Cervical dislocation severs the spinal cord and ruptures blood vessels in the neck, disrupting blood-flow to the brain, both of which help to assure brain death. Cervical dislocation should not be carried out without prior stunning as it is unlikely to cause immediate unconsciousness, and is likely to cause severe pain and distress (Erasmus et al., 2010). In successful cervical dislocation, the neck is stretched suddenly to instantly damage the brain stem, at the same time as the diameter

of the common carotid arteries is reduced, resulting in death by cerebral ischemia. Crushing achieves a somewhat different effect, as blood flow through the common carotid arteries is not reduced. If the spinal cord is severed by crushing, but blood-flow to the brain is not impeded, death from asphyxia will result (Martin et al., 2016d).

SL2.1c Summary

Regardless of the stunning and killing methods selected, it is important that unconsciousness induced by stunning lasts until brain death has occurred. For this reason it is important that the stun results in unconsciousness that lasts for an appropriate duration, and that a subsequent killing step is carried out quickly. Animals should be monitored to ensure that signs of consciousness do not return.

SL2.2 Electrical stunning

SL2.2a Principles

Electric stunning causes unconsciousness in birds by passing an electric current through the brain. A bird may be killed by this method if the electric current, applied at low frequency (e.g. 50 Hz), also passes through the heart causing cardiac fibrillation. A risk with electric stunning is that an electric current that is too small to cause unconsciousness may paralyse the bird or cause cardiac fibrillation without unconsciousness, giving a false impression of a stun and resulting in severe pain and distress.

SL2.2b Electrical water-bath stunning

Electrical water-bath stunning systems are commonly found in high throughput abattoirs, and can typically handle ten thousand birds per hour. This method of slaughter is commonly used for laying hens, broilers, duck, geese, turkeys and guinea fowl. The birds are removed from their transport crates, and manually inverted and hung by placing their feet into steel shackles on a moving processing line. The shackle line transports the birds to the electrified water-bath. At the start of the water-bath the birds' heads fall into the water and an electrical current passes from the water through the head, body and legs of the birds to the metal shackle. The circuit is completed because the shackle makes sliding contact with a stationary earthed rubbing bar. If sufficient current of an appropriate low frequency (e.g. 50 Hz) passes through the bird, it causes immediate loss of consciousness and cardiac fibrillation (sometimes termed "stun-to-kill"). At higher electrical frequencies it is possible to stun the birds but not fibrillate the heart. This increases the risk of recovery but may reduce carcase downgrading. The possibility of recovery may be necessary to meet halal slaughter requirements. Electrical parameters should be set to ensure immediate loss of consciousness, and so submersion of the head should not be a welfare concern.

Welfare risks and compromises

The welfare risks and compromises of the electrical water-bath include:

- (1) The birds are removed from their transport crates and handled at speed
- (2) The birds are inverted and suspended from a shackle
- (3) The shackle is likely to put pressure on the legs causing pain
- (4) The birds are at risk from painful pre-stun electric shocks as they approach the water-bath
- (5) Wing flapping due to these stresses can result in broken wings
- (6) Agitated birds may occasionally struggle and avoid being electrically stunned
- (7) The electric current delivered to each bird varies and so some birds may not be adequately stunned.

These welfare compromises can be reduced by good staff training, well-designed and maintained equipment and correct parameter selection, however they cannot be completely avoided.

Shackling

The need to shackle and invert live and conscious birds is a significant welfare concern. For chickens, the process of handling, inversion and shackling is stressful (Debut et al., 2005; Bedáňová et al., 2006; 2007; Fidan et al., 2015), and for some other birds the situation is worse. The large weight of turkeys suggests that they will be handled less smoothly and with less control. Geese are frequently very difficult to handle and flap violently. Laying hens are likely to have brittle or broken bones (Knowles and Wilkins, 1998). Shackles take the form of metal bars formed to create tapered slots for each leg. Hanging from these shackles compresses and strains the legs and joints. Sparrey (1995) reports that forces of five or ten times the birds' weight are frequently used to pull the birds into the tapering gap of the shackles resulting in severe compression of the bird legs by forces of around 180 N. Gentle and Tilston (2000), have shown that the legs of poultry are well supplied with nociceptors and so conclude this leg compression is likely to be painful. This pain may be worse for

birds suffering from disease or abnormalities of leg bones or joints (Danbury et al., 2000). Male birds (which usually have thicker shanks) struggle sooner and longer than female birds, suggesting that the thicker the shank and the greater the compression, the more distress is experienced (Satterlee et al., 2000). Flapping and struggling is likely to cause further distress to birds, because of the potential for broken, bruised and dislocated wings (Jones et al., 1998), and because flapping increases the likelihood of pre-stun shocks caused by the birds' wings contacting the electrified water before the head enters the bath. Agitated birds can sometime flap their wings and avoid making any contact with the water-bath. They would therefore be bled while conscious.

Low lighting and/or blue lighting in the shackling area can help to reduce struggling and wing flapping by birds directly after shackling (Prayitno et al., 1997; Jones et al., 1998) as can the presence of a curtain that the birds can lightly rest against, known as a breast comforting plate (Jones et al., 1998). The duration for which birds are on the shackle line should be controlled. If it is too long they suffer and it is too short they may still be struggling and flapping their wings as they approach the water-bath. It has been suggested that broilers should be allowed to settle on the shackles for a minimum of 12 s, before entering the water-bath since research has shown that after this time the majority of birds have stopped flapping (Gregory and Bell, 1987). However, longer shackling durations are associated with increased corticosterone levels compared to shorter durations, particularly when shackling exceeds 60 s, indicating increased stress (Fidan et al., 2015).

Some solutions to the problems caused by crushing in the shackles and inverting and suspending the birds have been proposed. These include a breast support conveyer and compliant shackles which conform to the size of a bird's legs (Lines et al., 2011; 2012). Neither development has been taken up commercially although the breast support conveyor has been built and used successfully in several small poultry processing lines. Industry experience suggests that it is particularly beneficial for turkeys.

Water-bath design

To ensure uniform current delivery along the water-bath, the electrode should run along the bottom of the full length of the water-bath (Schutt-Abraham and Wormuth, 1991). In areas of particularly low water conductivity the electrical conduction water can be improved by a small amount of food-grade salt (Bilgili, 1992). However the effect of adding salt to the water-bath may be short-lived as the water is changed while the system is in use (Perez-Palacios and Wotton, 2006).

Pre-stun shocks cause both carcass damage and poor welfare (Rao et al., 2013). These can be minimised by using a level shackle line, rather than one that dips down at the water-bath since this stimulates birds to flap their wings, risking their wing-tips entering the water before their heads. Pre-stun shocks are also reduced by use of an entry ramp which is designed so that it only lightly holds back the birds as they pass over it. It must be electrically isolated from the electrified water and must not permit the water to overspill onto the ramp (Gregory and Wotton, 1991). In Europe many retail poultry buyers require a routine third party welfare audit of water-bath systems, including the use of specialised measurement systems to detect pre-stun shocks.

Electrical parameters for water-bath stunning of poultry

The strength of the electrical stun experienced by the birds is determined primarily by the current that flows through the birds. The magnitude of this current is dependent on the voltage of the water-bath and on the electrical resistance of the bird. This resistance varies between birds and with bird size, age, breed and sex. Because of the individual variation in bird size within a flock each bird on a shackle line will receive a different electrical current. It is important to ensure that the voltage of the water-bath is set so that the highest resistance birds receive an adequate stunning current. This can have commercial consequences since use of excessive current can cause carcass quality problems such as blood splash in the breast meat and broken pectoral bones (Knowles and Wilkins, 1998; Wilkins et al., 1998). There is therefore a competing commercial pressure to avoid using excessive current. The performance of the electrical water-bath stunner must therefore be continuously monitored, measuring the average current and observing birds for signs of consciousness. Stunning current variation between individuals on the line can be reduced, but not eliminated, by processing single sex flocks of a uniform size. Deep immersion of a bird's head requires less voltage to achieve a given current, compared to shallow immersion (Raj and O'Callaghan, 2004a), so ensuring that the height of the water-bath allows all birds' heads to be well submerged will help achieve uniform stunning. Wotton and Wilkins (2004) report that the major variation in bird resistance is caused by the leg size, and the interface between the bird's leg and the shackle.

A solution to the problem of different birds receiving different electrical currents due to their individual resistances is constant current stunning (Sparrey et al., 1993) which enables each bird to be exposed to the same current. Although this has been shown to benefit bird welfare and carcass quality (Wilkins et al., 1999), no commercial equipment to achieve this is available, because of the increased complexity of the electrical connections.

More recently Lambooij et al. (2008; 2010b; 2012) have investigated making electrical contact with the bird's cloaca rather than through its legs. Since the legs are removed from the current path this is likely to result in less variation in resistance between birds and hence fewer birds will receive too much current. This work has also been shown to be technically

feasible and to have demonstrable advantages however it seems unlikely to be developed for commercial use, partly due to the difficulty in accurately placing a cloaca electrode in a commercial setting (European Commission, 2012).

Achieving an adequate stun depends on the electrical parameters used in the water-bath. The key electrical parameters are the electrical current, the frequency and the waveform. An electrical stun is generally driven by either an alternating voltage waveform (AC) or a pulsed direct voltage waveform (pDC).

With an AC system, the voltage oscillates continuously between a positive and a negative potential with respect to ground. This voltage signal may be sinusoidal, square or another pattern. The key parameters to be measured are the frequency of the oscillation, the root mean square (rms) voltage delivered and the resulting rms current flowing through the birds. Root mean square (rms) is a measure used to characterise the magnitude of a rapidly changing signal. Average or mean voltage cannot be used because the arithmetical mean of an alternating signal is always zero since it is equally positive and negative.

With a pulsed direct current system (pDC), the voltage always has the same polarity and is alternately zero and either positive or negative. Such a voltage signal is generally easier and cheaper to produce than an AC voltages. A pDC system can be electrically described in a range of ways. The key parameters apart from voltage and current are the frequency of the pulses and the proportion of the time that the voltage is not at zero. This is termed the duty cycle and expressed as a percentage. Alternatively, the duration for which the voltage is present in each cycle can be measured. This is called the pulse width and is measured in seconds. The voltage (or current) can be quantified as either the peak voltage, the average voltage or the rms voltage. However, it is important to understand that the terms average and rms are not synonymous and so average voltages cannot be directly compared with rms voltages (Figure SL1).

The rms voltage of a pulsed DC system with rectangular pulses is calculated as

$$V_{\text{max}} / \sqrt{\text{duty cycle}}$$

whereas the average voltage is

$$V_{\text{max}} / (\text{duty cycle})$$

The value of the rms voltage is always greater than the value of the average voltage. If the duty cycle is 50% then the rms voltage will be 1.41 x average voltage.

Many modern, digital voltage meters are not able to correctly measure the rms of a pDC signal. They need a setting identified as "AC+DC". However, with appropriate equipment the measurement of the water-bath rms voltage is a relatively trivial task, as is the measurement of the total current passing through all the birds that are in the water-bath. These measurements should be made continuously. Measurement of the current passing through an individual bird is significantly more difficult and currently not possible on a continuous basis.

The most reliable means of determining unconsciousness is by measuring brain activity using EEG signals. Behavioural indicators of insensibility are less reliable. There are two main bodies of research into the effectiveness of electrical water-bath stunning for broiler chickens. These are by Raj et al. (2006a; 2006b; 2006c) and by Prinz et al. (2010a; 2010b; 2012). Many other papers investigate smaller areas of this subject (e.g. Girasole et al., 2015) but no other bodies of work cover a wide range of parameters and base the conclusions on unconsciousness as determined by EEG measurements rather than the less reliable behavioural indications.

The criteria that both Raj and Prinz use to identify unconsciousness is that the measured electroencephalogram (EEG) signals show suppression to less than 10% of the pre-stun power levels in the two key frequency bands: 2 - 30 Hz and 13 - 30 Hz. The 2 - 30 Hz frequency band in EEG is associated with all states of consciousness, and the narrower 13 - 30 Hz band is associated with sensitivity to stimuli and the ability to process information.

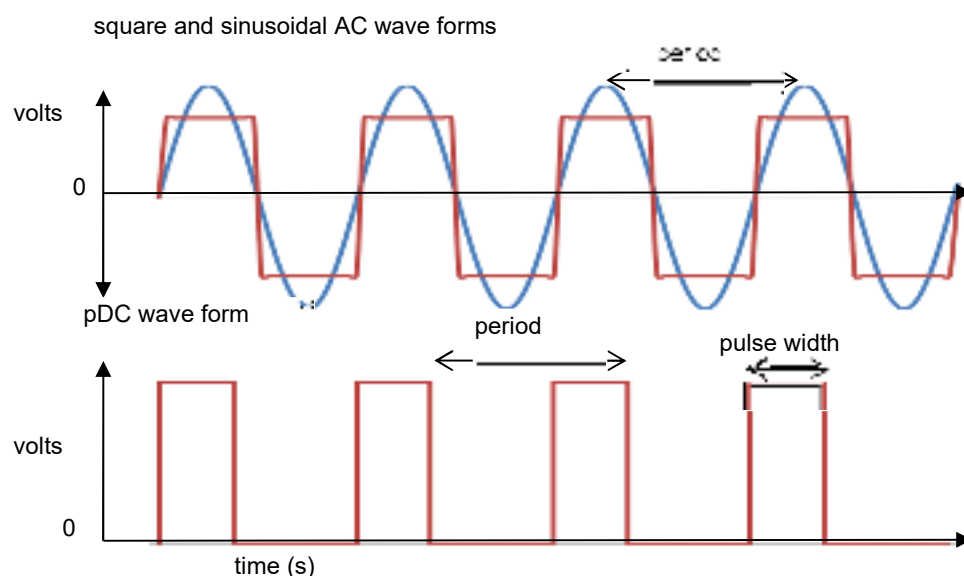


Figure SL1: Illustration of alternating (AC) and pulsed direct (pDC) voltage wave forms.

The frequency is calculated as the reciprocal of the period where the period is measured in seconds. The duty cycle is pulse width / period.

There are some procedural differences between the two pieces of work which may be responsible for the slightly differing results. The key differences are:

Raj:	Prinz:
uses a 1 second stunning current	uses a 10 second stunning current
cuts the neck to bleed within 8 s	does not cut the neck to bleed
uses on average 8 birds per treatment	uses on average 15 birds per treatment
requires >80% of birds to be unconscious	requires >90% of birds to be unconscious

A summary of the comparative results of Raj and Prinz is given in Figure SL2, together with the recommendations of the European Food Safety Authority (EFSA, 2012) and the recommendations of the Humane Slaughter Association (2015). For Raj the green squares mark treatments that resulted in at least 80% of the birds displaying signs of unconsciousness. For Prinz the green squares mark treatments where at least 90% of the birds displayed unconsciousness and there was recovery in less than 20% of the birds. The yellow squares mark treatments where only 85% of the birds displayed signs of unconsciousness or there were significant amounts of recovery.

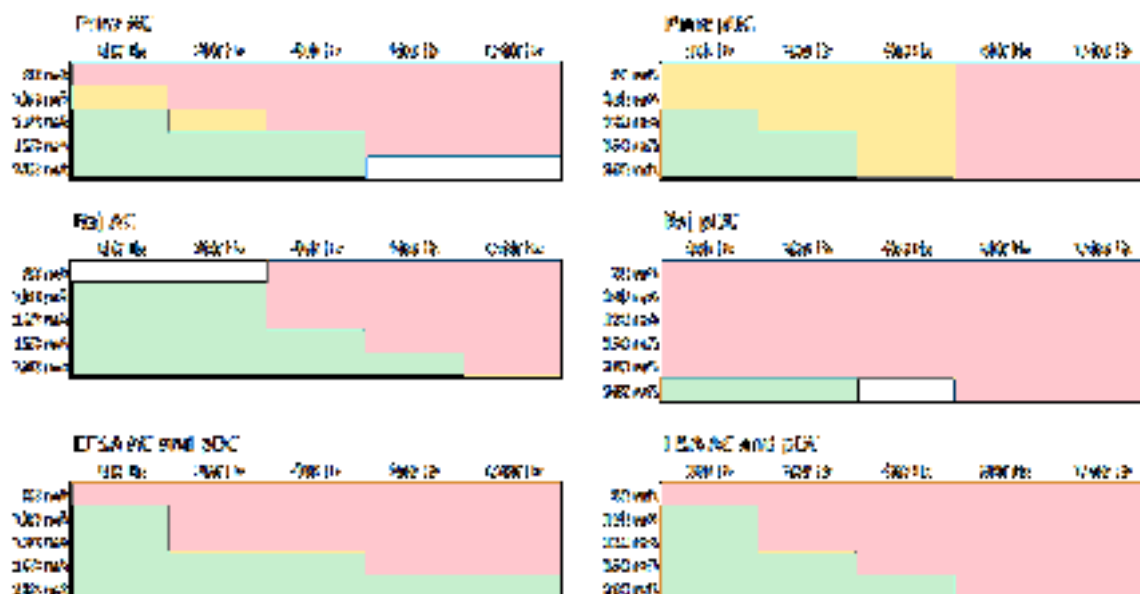


Figure SL2: Effective (green), marginal (yellow), ineffective (pink) and untested (white) combinations of frequency and stun current for broilers as determined by Prinz and Raj for AC and pDC currents, and EFSA and HSA recommendations. mA: milliamperes

The AC stunning results of Raj and Prinz are in broad agreement with each other and with the EFSA and HSA recommendations, with the exception that neither Raj nor Prinz suggest that a reliable stun can be achieved at frequencies in excess of 800 Hz, even though it is accepted by EFSA (EFSA, 2012; Humane Slaughter Association, 2015).

The pulsed DC results however differ significantly between Prinz and Raj. Prinz suggests that this is due to the difference in durations of exposure to the current. Neither EFSA nor the HSA differentiate between AC and pDC currents. If this is the case, then it is important that any use of pDC results in a long electrical exposure (e.g. 10 s).

The current that flows through each bird is determined by both the voltage of the water-bath and the electrical resistance of the birds, and can be calculated from the equation:

$$I = V/R$$

where I is the current measured in amperes (A), V is the voltage measured in volts (V) and R is the resistance measured in ohms (Ω). The Humane Slaughter Association (2015) provide indications of the various typical bird resistances as follows:

Table SL1: Typical electrical resistance of various types of bird. Data from HSA (2015)

Bird	Typical resistance
Female broiler	1200 Ω
Male broiler	900 Ω
Laying hen	1500-1900 Ω
Turkey	1200-2300 Ω
Guinea Fowl	2900 Ω
Duck	1600-2600 Ω
Goose	1900 Ω

These figures indicate the wide range of impedances that are to be found and underline the importance of adjusting the electrical parameters to ensure that an adequate stunning current is delivered rather than using a set voltage.

Summary

Electrical water-bath stunning is the most widely used and most widely researched slaughter technique for poultry. It can result in immediate and long-lasting unconsciousness which, when followed rapidly by reliable bleeding, results in death without recovery. The approach however includes inherent welfare compromises and the system requires careful setup and constant management to protect bird welfare.

SL2.2c Head-only electrical stunning

Head-only electrical stunning is the process of applying an electrical current across the head of the bird and not through its entire body. This is well established practice for electrically stunning pigs, sheep and other small livestock. It is well suited to killing small numbers of birds on a farm where it can be done with a simple hand held device. Head-only stunning has also recently been developed as an automated high speed system for commercial broiler processing plants. It aims to process broilers as quickly as an electrical water-bath system but to offer higher standards of welfare and carcase quality. Such systems are manufactured by the Dutch companies, "Top Kip" (www.topkip.com) and "Dutch Vision" (www.dutchvisionsolutions.com). At present there is limited uptake, possibly because of the complexity of the machinery.

Welfare advantages and disadvantages

Head-only stunning is almost always reversible, since the heart is not fibrillated. Rapid and efficient bleeding is therefore even more important than for electrical water-bath stunning. Since the electrical current does not pass through the body the prevalence of carcase damage such as blood splash in the breast muscle is reduced so there is less commercial pressure to minimise the stunning current used. Head-only stunning devices stun each bird separately so they can be configured as constant current stunners, automatically adjusting their voltage in order to deliver a preset current. This means that each bird can receive an appropriate current regardless of the variations in electrical resistance of the birds' head and feathers.

Since head-only stunning produces a stun from which the birds can recover, the approach is accepted for halal slaughter by many Islamic authorities. The birds can be properly stunned without risk of death. This contrasts with water-bath stunning where in order to ensure that the birds can recover, the quality of the stun may be compromised.

With the automated high speed head-only broiler systems, although the birds are restrained in an inverted position on something similar to a shackle line, they do not need to make electrical contact through the shackle therefore the legs do not need to be tightly held. To constrain the birds and prevent wing flapping as a result of the clonic-tonic spasms, the birds are held in an inverted cone. This may have a calming effect on the birds (Lambooij et al., 2014).

For manual head-only stunning the electrodes may be mounted on tongs to clamp around the head. These electrodes are likely to be plates with pins or spikes, which make contact with the bird's head through the feathers. Spiked electrodes provide only a few points of contact, so if they are dirty or in poor condition they may introduce added electrical resistance, reducing the current delivered to birds and resulting in an inadequate stun. Alternatively, operators may press the electrodes into the birds' heads with more force to try to overcome the poor electrical contact between the tongs and bird, risking pain or injury (Gibson et al., 2016).

Research into the welfare aspects of head-only electrical stunning

Lambooij et al. (2010a) reports investigations into the effect of a 50 Hz AC stunning current of 320 mA across the heads of broilers. This current was applied for 3 s or 5 s. Observation of the bird EEG suggested that they were unconscious for 44 s and 65 s respectively however an alternative EEG analysis method using the "correlation dimension" approach suggested a much shorter, 20 s, period of unconsciousness. Lambooij et al. (2014) reports further work on head-only stunning using a 50 Hz AC current of 260 mA applied for 3 s. EEG analysis was used to confirm unconsciousness but not to identify the unconsciousness duration.

Gibson et al. (2016) reports durations of insensibility of less than 20 s using 50 Hz AC stunning currents of 400 – 500 mA and an exposure of 7 s. Gibson tested two types of electrodes: the traditional spiked electrodes positioned on either side of the head, and two flat plates set at right angles into which the head is pressed so making contact with the left and right rear quarters of the head. The results suggested that this alternative electrode placement resulted in yet shorter periods of unconsciousness and so should be used with even more caution.

Somewhat earlier Raj and O'Callaghan (2004b) investigated head-only stunning of broilers using AC stunning currents of 50, 400 and 1500 Hz and currents of 100 mA and 150 mA applied for 1 s. The duration of the resulting unconsciousness was identified as 30 s – 40 s with the exception of the lowest current and the highest frequency (100 mA, 1500 Hz) where recovery was significantly faster. EFSA (2004) recommends a minimum rms current of ≥ 240 mA (50Hz AC) for effective head-only stunning of chickens.

These results suggest that over a wide range of practical voltages and exposure durations the duration of unconsciousness following head-only stunning is around half a minute. Bleeding must therefore take place quickly

following head-only stunning. The time from the start of bleeding to brain death for a broiler that is stunned and bled with a ventral neck cut is around 20 s (Raj et al., 2006a).

SL2.3 Controlled atmosphere stunning and killing (CAS)

SL2.3a Principles

Normal air comprises 78% nitrogen, 21% oxygen, 1% argon and less than 0.05% carbon dioxide. In controlled atmosphere stunning, the ratios of these gases are changed so that the birds lose consciousness and then die due to excess carbon dioxide and/or insufficient oxygen. Excess carbon dioxide in the breathed atmosphere causes acidification of the blood (hypercapnia), which in turn leads to acidification of the cerebrospinal fluid. This depresses brain activity causing a loss of vigilance, loss of consciousness and ultimately death. Insufficient oxygen in the breathed atmosphere air results in hypoxia and acidification of the cerebrospinal fluid leading to unconsciousness and death (Terlouw et al., 2016).

Gas mixtures that are commonly identified in reports are:

- Carbon dioxide added to air: at concentrations below 40% this can lead to unconsciousness within 30 s and at concentrations above 50% it leads to a death within 4 minutes. Carbon dioxide however promotes respiratory disruption (hyperventilation) and high levels are also probably pungent and aversive (McKeegan et al., 2005; 2006; 2013a; Gerritzen et al., 2013a).
- Low levels of carbon dioxide (e.g. 30%) added to inert gas: this creates a carbon dioxide rich hypoxic atmosphere which results in quicker unconsciousness and death than carbon dioxide alone but it is less aversive than high levels of carbon dioxide and it results in fewer convulsions than high levels of inert gas (Abeyesinghe et al., 2007; McKeegan et al., 2007a).
- Low levels of carbon dioxide with added oxygen, for example 40% carbon dioxide and 30% oxygen in nitrogen (30%): this leads to unconsciousness more gently with fewer convulsions than low levels of carbon dioxide alone, but time to death would be long (McKeegan et al., 2007a). This is therefore used as the stunning phase of a bi-phasic stunning and killing system.
- High levels of inert gas such as nitrogen or argon (e.g. 90%): this reduces the atmospheric oxygen content to 2% or less and so results in a rapid loss of consciousness and death with little respiratory disruption. It can result in convulsions such as wing flapping which may occur before the possibility of consciousness can be fully excluded (Gerritzen et al., 2000; McKeegan et al., 2007a).

SL2.3b Welfare advantages and disadvantages

Controlled atmosphere stunning benefits poultry because they do not have to be disturbed, handled or removed from the crates in which they were transported. This may be particularly beneficial to end-of-lay hens which are likely to have brittle or broken bones (Knowles and Wilkins, 1998), and for birds that react strongly to handling, such as geese. No direct contact needs to be made with the bird and positioning of the bird is not important. A second advantage of CAS is that its effectiveness is relatively insensitive to variations in bird size and conformity so a properly set up system does not need adjustment to suit different flocks, neither does it underperform when presented with flocks with a large variance in bird size. Recovery can be avoided with a high degree of certainty without compromising meat quality by ensuring the final gas concentrations are applied at a high enough level and for a long enough time. It is less clear whether both unconsciousness and eventual recovery can be assured as would be required to conform with halal requirements. Birds stunned with carbon dioxide can recover very rapidly following removal to a normal atmosphere (McKeegan et al., 2013a). CAS stunning of poultry for the halal market is, however, to be found in some European countries.

Welfare concerns around this method of slaughter focus on the aversiveness of the gases, the respiratory disruption caused and on the possibility that involuntary convulsions including wing flapping might occur before all the birds are fully unconscious.

SL2.3c Practical implementations of controlled atmosphere stunning

Commercial application of controlled atmosphere stunning is achieved using a range of approaches. In poultry processing plants these include:

- a pit into which transport crates of birds are lowered for a period of several minutes. This takes advantage of the fact that carbon dioxide is significantly heavier than air so the gas is contained in the pit and the concentration at the top of the pit is lower than at the bottom.
- a tunnel along which the birds, either in or out of their transport crates, are transported within a modified atmosphere.
- a static chamber into which poultry transport crates are introduced. The chamber is then sealed and the level of carbon dioxide in the chamber is raised.

Timings vary with gas concentrations but typically birds may be expected to lose consciousness within 20 s – 1 minute and all the birds may be expected to be dead within 5 minutes (Raj, 2006).

For on farm emergency killing a deep container may be filled with carbon dioxide and compromised animals are simply lowered into this container. Depending on the level of sophistication the carbon dioxide level may or may not be continuously measured.

For commercial killing of chicks or small numbers of other birds, equipment is available into which the birds are placed. Once sealed, a suitable gas mixture is injected into the unit until death is assured.

On farm disease control may be achieved by whole house killing. Bird houses are appropriately sealed and then filled with either with carbon dioxide gas or with a high expansion carbon dioxide or nitrogen filled foam. Whole house killing of laying hens using carbon dioxide gas is practiced in some countries.

SL2.3d Research into welfare aspects of controlled atmosphere stunning

Welfare research has focused on the behavioural and physiological reactions of chickens to controlled atmosphere environments. This can be divided into two parts: the responses of the conscious bird and the involuntary responses of the birds as they start to lose consciousness. Most research has focused on responses of single birds (Webster and Fletcher, 2001; 2004; McKeegan et al., 2006; Sandilands et al., 2011) however some later work also includes research with small groups of birds (Abeyesinghe et al., 2007) and birds in a commercial stunning environment (McKeegan et al., 2007b; 2013a). There is some evidence that birds in groups may detect changes in atmosphere at an earlier stage than individual birds but that they exhibit fewer signs of stress.

Gerritzen et al. (2007) compared the responses of ducks, broilers, hens and turkeys to carbon dioxide and concluded that while there are some small differences between the species, which might also be age related, the differences are not so substantial so as to make it necessary to set different welfare criteria.

SL2.3e Responses of the conscious bird

Humans report high levels of carbon dioxide as being aversive, and it seems that similar aversion is also experienced by other mammals and birds. Carbon dioxide is perceived as pungent at concentrations above 30% (Raj et al., 1992) and at 40% elicits painful responses (Anton et al., 1992). Pigs have also been shown to respond strongly to high levels of carbon dioxide, refusing to enter an area of 90% carbon dioxide to eat even after a period of fasting (Raj and Gregory, 1996).

For humans, inhalation of carbon dioxide also results in a powerful and urgent sensation known as air hunger. This response can be seen in other mammals and in birds. It can be observed during carbon dioxide stunning of chickens as respiratory disruption (McKeegan et al., 2007a).

Despite the above factors, evidence for aversion in broilers is not clear. Trials show that broilers can detect carbon dioxide in the atmosphere at concentration of 10% and they respond to this with head shaking, mandibulation and in pauses between feeding bouts (McKeegan et al., 2006; Sandilands et al., 2011). These responses generally increase with increasing concentrations of carbon dioxide but it is not clear that these behaviours are indications of distress. Headshaking is higher when hens are in a somnolent state than when they are awake and more frequent in chickens exposed to argon rich atmospheres than carbon dioxide. It is thought to be an alerting response, functioning to promote arousal in the face of reduced sensibility (Webster and Fletcher, 2001; Abeyesinghe et al., 2007). Mandibulation is thought to be related to gustatory or trigeminal stimulation by the carbon dioxide (McKeegan et al., 2005).

Respiratory disruption is observed in response to carbon dioxide at all levels from 10% to 70% but seldom occurs when inert gases are used without increased levels of carbon dioxide. This behaviour takes the form of prolonged deep breathing with open bill and is linked to an increase in the tidal volume of breathing of up to a factor of ten. Figure SL3 illustrates this breathing pattern. It is not known how strongly this impacts on the bird's welfare. Surprisingly, in two separate trials, it was found to be most common at 25% carbon dioxide and did not increase with carbon dioxide concentration. At carbon dioxide levels of 40%, 55% and 70%, only 20% - 30% of the birds exhibited this behaviour (McKeegan et al., 2006; 2007b; Abeyesinghe et al., 2007).

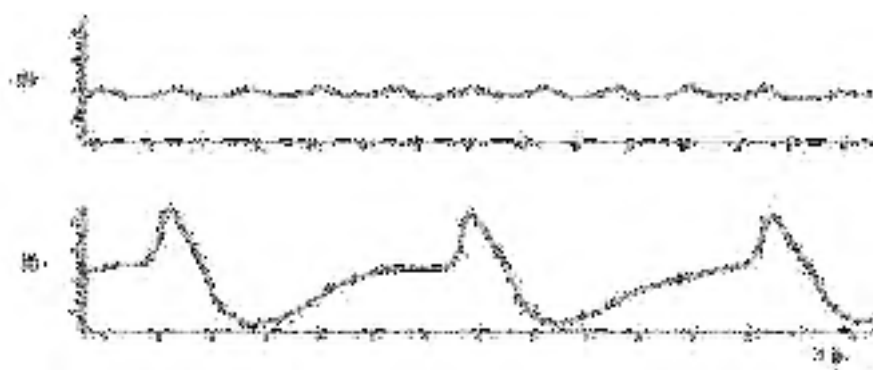


Figure SL3: Example traces showing normal (a) and deep breathing in broilers in response to a hypercapnic gas mixture containing 40% carbon dioxide, 30% oxygen and 30% nitrogen. Y scale units are identical and X scale units are 1 second (from McKeegan et al., 2007a).

The clearest indication of aversion is withdrawal from a feeder where carbon dioxide is present. McKeegan et al. (2006) found that less than 20% of broilers withdrew from a feeder in the presence of 40% carbon dioxide and even at 55% and 70% carbon dioxide less than 40% of the broilers withdrew. Similar results are reported by Webster and Fletcher (2004) and by Gerritzen et al. (2000).

Despite not withdrawing to avoid carbon dioxide exposure, it has been shown that chickens will avoid exposure to hydrogen sulphide (McKeegan et al., 2005). This indicates that chickens are able to respond to a noxious atmosphere by withdrawing. However McKeegan et al. (2005) note that hydrogen sulphide is detected as an olfactory stimulation whereas carbon dioxide results in trigeminal stimulation so the comparison is not perfect.

In comparison to carbon dioxide, exposure to high concentrations of the inert gases nitrogen or argon (resulting in low levels of oxygen) results in very low levels of respiratory disruption and mandibulation (Lambooij et al., 1999a; Webster and Fletcher, 2001; Abeyesinghe et al., 2007), but high levels of headshaking. Webster found that chickens entering an argon rich atmosphere hesitated less than when they entered a carbon dioxide rich atmosphere (Webster and Fletcher, 2004).

Two other mixtures have been investigated for aversiveness: these are carbon dioxide with elevated levels of oxygen; and an anoxic mix of carbon dioxide and inert gases. Reports of tests which might indicate the comparative aversion to carbon dioxide, carbon dioxide with oxygen, and carbon dioxide with an inert gas have not been found.

SL2.3f Involuntary responses as the birds lose consciousness

As birds lose consciousness another range of behaviours can be observed. These include bouts of wing flapping, loss of posture, leg paddling, twitching and jumping. The behaviour that gives most cause for concern is the wing flapping since this can lead to broken or dislocated wings. It is important to avoid this occurrence while birds are conscious. McKeegan et al. (2007b) recorded EEG signals from birds being stunned by inert gas (hypoxia), by carbon dioxide with an inert gas (hypercapnic hypoxia) and a bi-phasic stun comprising 60 s of 40% carbon dioxide with 30% oxygen (hyperoxic hypercapnia) followed by exposure to 80% carbon dioxide. This data showed that in the hypoxic atmospheres and the hypercapnic hypoxic atmospheres much of the wing flapping occurred before the EEG signals became suppressed, meaning that the possibility of consciousness cannot be fully excluded. Trials with the bi-phasic stunning and killing indicated that no wing flapping occurred until the EEG signals were suppressed indicating that the birds were unconscious. The number of bouts of wing flapping and the duration of these bouts was also lower with the bi-phasic stun compared to the hypoxic atmosphere. Gerritzen et al. (2013a) reports trials using carbon dioxide without other added gases where the carbon dioxide concentration is increased in a series of steps. In one approach the carbon dioxide concentration is increased in four steps from zero to 40% in 240 s after which the concentration rose rapidly in one more step to 65%. In the second the concentration of carbon dioxide rose in three steps from zero to 50% in 135 s after which the concentration rose rapidly in one more step to 65%. In the case with more rapid rise in carbon dioxide concentration some wing flapping was observed before the EEGs showed strong suppression. However, with the more gradual rise in concentration no wing flapping occurred until more than one minute after the EEGs showed suppression. FAWC (2012) proposed that the use of a gradually increasing concentration of carbon dioxide produced an acceptable stun/killing system for broilers.

SL2.3g Summary

The advantages of controlled atmosphere stunning are that the birds do not need to be handled or positioned and that it is a robust system insensitive to bird size or conformity able to stun and kill 100% of birds.

The disadvantages of CAS systems are that during the time it takes to lose consciousness the birds may experience the unpleasant effects of carbon dioxide exposure, and convulsions including wing flapping resulting in broken bones may occur while they have some level of consciousness. There remains uncertainty about how aversive chickens are to the respiratory disruption caused by the carbon dioxide and also about the state of consciousness of the birds when they experience convulsions. The risk of these two welfare compromises is minimised by the exposing the birds first to low concentrations of carbon dioxide, possibly with enhanced levels of oxygen for a period of around 1 minute before increasing the carbon dioxide concentration to ensure the birds are killed.

SL2.4 Whole house killing

SL2.4a Principles

Whole-house killing is carried out on farms when it is considered advantageous to kill birds on location, rather than catch and transport them to a slaughter facility. This can be used for end-of-lay hens to avoid the need to handle and transport them (Berg et al., 2014) and for disease control purposes. Carbon dioxide gas or high expansion gas filled foam is used for whole house killing.

SL2.4b Carbon dioxide gas

Turner et al. (2012) investigated whole house culling with carbon dioxide and found that laying hens lost consciousness within 2 minutes of the gas concentration reaching 20%. The gas concentration continued to rise to 60% and brain death followed within less than 5 minutes. Only mild to moderate head shaking and gasping was observed and one or two convulsions per bird. Releasing compressed gas into a space has a cooling effect, much like a refrigerator. Although very low temperatures were measured inside the barns (-23 °C), the core body temperatures of birds remained at or near normal while birds were alive. There are technical solutions to the problem of the cooling caused by the expanding gas. Whole house gas killing may not work effectively where barns cannot be sealed, and so this system may be best suited to colder climates, where barns are designed to strictly control air-flow in and out.

SL2.4c High expansion gas filled foam

For barns which cannot be easily sealed, high expansion anoxic foam may be a more appropriate option for on-farm whole house killing. A deep blanket of foam is created, that advances across the floor of the poultry-house, fully submerging all the birds. Foam is filled with either nitrogen or carbon dioxide, and residual oxygen levels in the foam are very low; less than 2% in most cases.

Post-mortem examination of birds killed with high expansion anoxic foam confirms that the cause of death is anoxia, and not occlusion of the airway (McKeegan et al., 2013a). High expansion gas filled foam therefore differs significantly from water-based air-filled foam, which causes mechanical hypoxia by occlusion of the airway (American Veterinary Medical Association, 2007) in a similar way to drowning and suffocation. The use of water-based air-filled foam is likely to severely compromise welfare.

EEG evidence from tests on hens, broilers ducks and turkeys in anoxic foam suggests that consciousness is lost 18-30 s after submersion in nitrogen filled foam, and between 1-16 s after submersion in carbon dioxide filled foam, depending on species. As foam generation begins, birds exhibit some fear responses, which McKeegan et al. (2013a) ascribe to the noise of the foam generation in the small experimental setting, and some gasping is observed when carbon dioxide filled foam is used. This is considered to be a response to carbon dioxide escaping from popping bubbles as they hit the sides of the test chamber. This blanket layer of carbon dioxide gas outside the foam has an effect on consciousness before birds are fully submerged. Once birds are submerged, there is little difference in the behavioural responses of the birds to nitrogen- and carbon dioxide-filled foams. Convulsions and wing flapping risk breaking down the foam very rapidly, and so the amount applied should be enough to generously cover the birds, even when some foam is broken down. With nitrogen filled foam, the destruction of foam would allow birds re-exposure to atmospheric air, and could result in a swift return to consciousness. This risk is smaller with carbon dioxide foam, as the density of carbon dioxide will ensure it forms a carpet of gas which is likely to envelop the birds.

SL2.4d Summary

On-farm whole-house euthanasia removes the need to capture and transport live birds. This is beneficial in that it removes the stress of capture, crating and transport; removes the risk of injury due to handling and transport and in the case of communicable disease, the risk of disease spreading is reduced.

The welfare disadvantages of carbon dioxide gas and high expansion gas filled foam for whole-house killing are much the same as those for CAS stunning and killing. The birds may experience unpleasant effects as a result of carbon dioxide exposure as unconsciousness is not immediate, and may suffer broken bones as a result of convulsions and wing-flapping as consciousness is lost.

SL2.5 Low atmospheric pressure stunning (LAPS)

SL2.5a Principles

Low Atmospheric Pressure Stunning (LAPS) induces unconsciousness through lack of oxygen (hypoxia). In contrast to controlled atmosphere stunning, LAPS does not require the introduction of gas to displace oxygen. Atmospheric pressure is gradually reduced over a period of minutes until it achieves the atmospheric pressure that is to be found at an altitude of about 13,000 m. The reduced partial oxygen pressure results in progressive hypoxia which eventually causes unconsciousness and then death. A reliable and irreversible stun is achieved (Martin et al., 2016a), and birds remain in their transport crates during the LAPS process, removing the need to invert and shackle conscious birds. In commercial use a LAPS system can process 11,000 birds per hour on each processing line. LAPS is a relatively new technology, and to the best of our knowledge has so far only been tested on chickens.

SL2.5b Bird responses to LAPS

Broilers subjected to LAPS exhibit a range of behaviours in keeping with progressive hypoxia. These are similar to those seen when birds are exposed to inert gas. EEG evidence suggests that birds may lose consciousness within 30-40 s (McKeegan et al., 2013b; Martin et al., 2016c).

Birds exposed to atmospheric pressure reduced from normal (approx. 100 kPa) to 29.5 kPa all exhibit loss of posture, and 75% of birds exposed to this pressure for a few minutes will not survive the treatment. When pressure is further reduced to 17.8 kPa 100% of birds are killed by the treatment (Purswell et al., 2007). A pressure of 19.4 kPa produces 99.99% mortality. The associated partial oxygen pressure (4.0 kPa) is similar to that achieved in inert gas CAS systems with good gas distribution (Purswell et al., 2007).

SL2.5c Practical application

LAPS for broilers is not yet approved for use in the EU but has been approved for use in the USA and Canada, and has been in regular use in one large poultry plant.

A stunning cycle takes 280 s in this system and the pressure follows a two-phase profile. Over the first 67 s of the cycle, pressure inside the chamber is reduced from approximately 100 kPa (atmospheric pressure) to 33 kPa. In the second phase, the pressure inside the chamber drops more slowly to a final pressure of approximately 20 kPa over 213 s.

SL2.5d Welfare advantages and disadvantages

Low atmospheric pressure stunning benefits poultry because they do not have to be disturbed, handled or removed from the crates in which they were transported. No direct contact needs to be made with the birds. A second advantage of LAPS is that its effectiveness is relatively insensitive to variations in bird size and conformity so stunning and killing can be achieved in 100% of birds with a high degree of certainty.

Welfare concerns around this method of slaughter focus on the aversiveness of the effects of low pressure and on the possibility that involuntary convulsions including wing flapping might occur before the bird is fully unconscious.

SL2.5e Research into welfare aspects of LAPS

Patterns of behavioural responses under LAPS are generally the same as under CAS, comprising ataxia, loss of posture, convulsions and leg paddling (Mackie and McKeegan, 2016; Martin et al., 2016b; 2016c). Some individual variation is seen in responses to LAPS (Mackie and McKeegan, 2016) just as in CAS (Abeyesinghe et al., 2007; Martin et al., 2016c) and for humans undergoing hypobaric chamber training (Gradwell and Macmillan, 2015). In chickens these differences are not accounted for by bodyweight (Mackie and McKeegan, 2016).

Humans undergoing gradual decompression leading to hypoxia report that although the experience varies for individuals, it is not generally unpleasant and they are unaware of their declining function. Occasionally, humans encounter problems related to the low pressures needed to cause hypoxia. As environmental air pressure drops, gas filled cavities in the body expand. Where pressure cannot be equalised, for example, if human subjects are unable to vent their digestive tract by passing wind, this expansion may become uncomfortable or painful (Gradwell and Macmillan, 2015). Vizzier-Thaxton et al. (2010) states that since the avian respiratory system is different from that of mammals, gas is unlikely to become trapped in the abdomen or lungs.

Typical pain related behaviour, such as active escape/withdrawal, guarding, sick-bird posture, freezing and vocalisation are not seen in LAPS (Martin et al., 2016a). There is no known direct indicator for pain in chickens (EFSA, 2013), but Martin et al. (2016b) suggest that the slow wave EEG observed in broilers held in darkness under LAPS indicates that they are not in pain. Even in darkness, a desynchronisation of the slow wave EEG (resembling waking from sleep) is observed when chickens are given an aversive sensory stimulus (Gentle, 1975). Martin suggests that the absence of any such desynchronisation indicates the absence of sensory stimulation, such as pain or discomfort.

Martin et al. (2016a) observed birds undergoing LAPS with and without analgesic interventions, to assess whether there were behavioural differences in birds which were insensitive to pain compared to untreated birds. Birds were administered butorphanol intra-muscularly at a dose of 1 mg/kg. Butorphanol was selected as it has characterised pharmacokinetics in birds (Guzman et al., 2014), and is the currently recommended opioid for use in birds (Paul-Murphy and Fialkowski, 2001; Paul-Murphy, 2013). Importantly, opioid analgesics (including butorphanol) are known to relieve acute pain at both central and peripheral sites, and target the affective component of pain. Because butorphanol is a partial agonist, respiratory effects are minimised, and there is evidence that butorphanol causes considerably less sedation than other opioids (Singh et al., 2017), which is important for assessing behavioural responses to LAPS with and without analgesia. The dose given has been shown to have analgesic effects in a variety of birds, including African grey parrots, Hispaniolan Amazon parrots and cockatoos (Curro et al., 1994; Paul-Murphy et al., 1999; Paul-Murphy and Ludders, 2001) and the same dose of a related kappa opioid agonist (U50488H) has been demonstrated as having an analgesic effect in chickens (Concannon et al., 1995). Butorphanol was administered 30 minutes before exposure to LAPS, and is effective for 1-2 hours (Paul-Murphy, 2013). Intra-muscular injection was selected as this method of administration ensures high bioavailability of butorphanol (Guzman et al., 2011; Gustaven et al., 2014) and avoids the variability of oral absorption of opioids.

Martin et al. (2016a) observed no overall difference in the range and patterning of behaviour responses shown by treated and untreated birds during LAPS. However, time to onset of ataxia, mandibulation and deep breathing were delayed in analgised birds. Analgised birds were less likely to display jumping and slow wing flapping behaviours, suggesting that these behaviours may be pain related, although the authors also point out that these behaviours could have been inhibited by the sedative and physiological side effects of the opioid analgesic used in the trial. The authors conclude that there is not convincing evidence that birds undergoing LAPS are experiencing pain.

Reported times to unconsciousness vary from 40 s (McKeegan et al., 2013b) to 81 s (Mackie and McKeegan, 2016). It is possible that this is due to the different ways of measuring consciousness because Mackie and McKeegan (2016) recorded loss of posture while McKeegan et al. (2013b) used EEG measurements. As LAPS is undertaken in darkness, low frequency waves associated with unconsciousness may have been confounded with the low frequency waves elicited by simulated eye closure. When LAPS takes place in an illuminated chamber rather than in the dark, time to unconsciousness increases from 92 s to 102 s (Martin et al., 2016b).

When EEG, electrocardiogram (ECG) and behaviour are all recorded at the same time, it appears that loss of posture coincides with the onset of reduced heart rate and changes in EEG associated with unconsciousness. Taken together, this suggests that unconsciousness sets in at 60 s. More conservative measures of unconsciousness might put loss of consciousness a little later; either at 75 s with the onset of clonic convulsions, or at 114 s, when the total power of the EEG signal reaches 10% of its pre-stunning baseline (Martin et al., 2016c).

SL2.5f Summary

LAPS has the potential to offer significant welfare benefits for poultry slaughter. Birds remain in their transport crates during LAPS stunning so there is no need for conscious birds to be shackled or positioned. Its effectiveness is relatively insensitive to variations in bird size and conformity so it does not underperform when presented with flocks with a large variance in bird size. No aversive gas is used to displace oxygen, and stunning is irreversible.

Concerns surrounding LAPS centre around spasms and wing flapping induced by hypoxia, as well as the potential for hypobaric injury. As environmental pressure is reduced, gas-filled cavities within the body expand. This has the potential to be painful and/or injurious if not properly controlled. Although the structure of the avian respiratory system makes it unlikely that air could be trapped in the lungs, any gases trapped in the digestive tract could expand and this could be painful. However, evidence from Martin et al. (2016a; 2016b) suggests that birds do not find LAPS painful.

SL2.6 Percussive stunning/blunt trauma/mechanical stunning

SL2.6a Principles

When small numbers of poultry have to be killed, e.g. for on-farm euthanasia of individuals, birds may be rendered unconscious percussively. Concussion can be induced using a mechanical captive bolt device or with a manual blow to the head of the bird with a suitably heavy object. To achieve a successful concussion, the aim is not to break the skull or cause immediate physical damage to the brain. Rather, concussion is induced by the sudden acceleration of the head caused by a sharp impact on the skull. If a skull is thin the percussive energy may be absorbed by fracturing the skull rather than causing the acceleration of the head required to cause concussion, so a stun might not be achieved. This can occur when an unsuitable device is used.

SL2.6b Practical implementation of percussive stunning

For mechanical stunning (i.e. using a captive bolt gun), selection of the appropriate size and shape of bolt head and firing energy are important to ensure that a stun is effective. Accurate placement and angle of the bolt gun are also critical; for chickens deviation of 20° or more can result in severe trauma without any loss of consciousness (Raj and O'Callaghan,

2001). When manual percussive stunning is carried out, selection of an appropriate instrument, and a well-placed blow of the appropriate weight can facilitate effective stunning even in larger birds such as turkeys. However, selection of the wrong instrument, for example, one which is too hard or with insufficient contact area can inflict fractures rather than achieving the acceleration of the head necessary for a good stun (Cors et al., 2015). Erasmus et al. (2010) reports a test using a pneumatic percussive stunner which appears to be underpowered for turkeys since two hits were required to achieve insensibility.

Percussive stunning should usually be followed with a killing method, such as bleeding or cervical dislocation to ensure that brain death occurs before any consciousness can be regained.

SL2.6c Welfare advantages and disadvantages

Percussive stunning is quick and cheap, produces an immediate stun, and can be carried out anywhere by experienced poultry stock-people. This means that euthanasia can be administered to individual sick or injured birds without delay and with a minimum of handling and transportation.

Disadvantages of percussive stunning include the potential for human error with potentially serious welfare impacts. Manual percussive stunning, or blunt trauma, achieved with a single well-placed blow to the head from a suitably heavy object is not suited to large numbers of animals. As operators become fatigued, accuracy in the placement and strength of the blow may decrease, which would have a negative welfare impact for the animals in question. Not all countries allow percussive stunning to be delivered by hand.

SL2.7 Killing of surplus or unthrifty chicks

SL2.7a Mechanical maceration

Although aesthetically unpleasant to many people, instantaneous maceration of chicks up to 72 h old and embryonated eggs is considered to provide humane euthanasia (Bandow, 1987), and this method is accepted in the recommendations of many authorities including EFSA, and the American Veterinary Medical Association. Chicks and poults older than 72 h should be stunned before maceration (EFSA, 2004).

Assessing welfare of chicks in macerators is necessarily difficult – there is no opportunity to analyse behaviour or time to unconsciousness. However, it can be assumed that welfare would be severely compromised if death was not instantaneous, and chicks were allowed to be injured by the maceration process before death. There are a number of design and procedural considerations which can reduce this risk, and these are outlined below.

EFSA (2004) recommend that only macerators specifically designed for the disposal of poultry should be used, and that these should have blades rotating at a minimum of 6,000 rpm.

There are two main types of macerators in commercial use for the disposal of chicks. Crushing macerators have either one roller that rotates against a solid projection, or contra-rotating interlocking rollers. The roller(s) are fitted with solid projections along their length. Rollers without projections result in chicks being flattened, rather than instantly fragmented. It is recommended that the area through which chicks are crushed (i.e. the gaps between the rollers, or between the side projections) should be no more than 10 mm (Humane Slaughter Association, 2007) although there is no known peer reviewed research to support or contradict this.

Knife-type macerators have rapidly rotating blades which effectively shred the chicks. These blades should be solid, radiating from a central axle, and may interlock with a grid. Sharp edges are not necessary as they cut effectively due to the high speed at which the blades rotate. Blades should be arranged around the axle in a pattern which ensures all chicks are killed immediately (Humane Slaughter Association, 2007).

Chicks should enter the machine at a rate compatible with its capacity, and should be introduced in single layers. This avoids blockages and machine stoppages, which would compromise welfare if chicks were partially macerated but not killed. Any drop from a conveyor into the working parts of the macerator should be minimised, and there should be no possibility of chicks bouncing or being deflected in the macerator (EFSA, 2004; Humane Slaughter Association, 2007).

SL2.7b Controlled atmosphere killing

CAS offers an alternative to mechanical maceration for the stunning and killing of day-old-chicks. It appears that chicks are very sensitive to residual oxygen levels, and even slight increases significantly increase the risk of survival.

Raj and Whittington (1995) describe tests of CAS mixtures for day-old chicks. They report that batches of 20 chicks exposed to mixtures of 20%, 30% or 40% carbon dioxide in argon resulted in death for all chicks within 2 minutes without severe respiratory distress when residual oxygen was below 2%. Keeping residual oxygen levels low appears to be critical; Raj and Whittington (1995) report that when residual oxygen levels in the above mixtures rose to 5%, some chicks survived for longer than 2 minutes. Chicks exposed to argon without the addition of carbon dioxide all died within 3

minutes when residual oxygen levels were less than 2%, but only slightly higher oxygen levels (3%) resulted in 20% of chicks surviving for 7 minutes.

SL3. FARMED BIRDS BY TYPE

SL3.1 Broilers

Broiler slaughter dominates the poultry slaughter literature, so much of the first part of this report is written around research on broilers. This section will therefore briefly repeat the most significant facts with a specific focus on broilers.

In Europe broilers slaughtered for production purposes are stunned and killed using the electrical water-bath or using controlled atmosphere stunning. In 2012 80% were killed using the electrical water-bath (European Commission, 2012) however each year the proportion of birds killed using controlled atmosphere stunning increases. The electrical water-bath system is still considered the most practical choice for small processing plants. Head-only stunning in commercial processing plants has seen relatively little uptake, however the concept is still very new. For on farm killing head-only electrical stunning is a common choice. For emergency on farm slaughter carbon dioxide immersion or whole house killing using gas or gas filled foam is suitable.

SL3.1a Electrical water-bath stunning

Electrical water-bath parameters for broilers have been extensively researched. Combinations of frequency and current for pulsed DC and AC stunning as identified in the two most significant bodies of work on this subject (Raj et al., 2006a; 2006b; 2006c and Prinz et al., 2010a; 2010b; 2012) are given in Figure SL2. For comparison, the recommendations of EFSA and the recommendations of the HSA are also given. The results of EEG investigations by Raj and Prinz are summarised below in Table SL2 and Table SL3, with adjustments made to compensate for different ways of measuring current between the two authors. It should also be noted that Raj and Prinz applied stunning currents for different durations; Raj used a 1 s application, whereas Prinz used a 10 s application. Although this may explain some of the differences between their findings, this is not certain. Results are displayed side by side in the table below for comparison.

Hindle et al. (2010) investigated the current required to stun broilers with square wave AC current at 50, 400, and 1,000 Hz. They indicated that effective stuns lasting a minimum of 1 minute would be achieved using currents of 125 mA at 50 Hz, 200 mA at 400 Hz, and 450 mA at 1,000 Hz. This is broadly in line with the findings of Prinz et al. (2010b) and Raj et al. (2006c), and also offers some insight into stunning at higher frequencies.

In these tables, data from Prinz et al. (2010b) are based on mixed male and female broilers. Stunning efficiency segregated by sex is not available. It is assumed that the same is the case for data from Raj et al. (2006c) although this is not specified. There is no known research demonstrating that different stunning currents are required to achieve unconsciousness for male and female broilers.

Broilers are frequently slaughtered segregated by sex to enable easier mechanical processing, and this allows the water-bath voltage to be adjusted to provide the required stunning current, taking account of the differences in resistance between males and females. Data from Prinz et al. (2010b) indicates that male broilers have an average impedance of 900 Ω whereas female broilers have a much higher average impedance, at 1200 Ω . This means that on average, the voltage required for female broilers is likely to be 30% higher than for males.

Table SL2: Water-bath stunning parameters for broiler chickens using AC current. Data from Prinz et al. (2010b) and (Raj et al., 2006c).

Application time	100 Hz		200 Hz		400 Hz		≥ 800 Hz
	1 second	10 seconds	1 second	10 seconds	1 second	10 seconds	1 s or 10 s
80 mA	inadequate stun	inadequate stun	inadequate stun	inadequate stun	inadequate stun	inadequate stun	inadequate stun
100 mA	> 80% unconscious No recovery within 8 s	85-90% unconscious Significant recovery within 40 s	> 80% unconscious No recovery within 8 s	<85% unconscious Significant recovery within 40 s	inadequate stun	inadequate stun	inadequate stun
120 mA	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	> 80% unconscious No recovery within 8 s	85-90% unconscious Significant recovery within 40 s	inadequate stun	inadequate stun	inadequate stun
150 mA	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	inadequate stun
200 mA	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	> 80% unconscious No recovery within 8 s	>90% unconscious <20% of birds recover within 40 s	inadequate stun

Table SL3: Water-bath stunning parameters for broiler chickens using pDC current. Data from Prinz et al. (2010a) and Raj et al. (2006b).

Application time	100 Hz		200 Hz		400 Hz		≥ 800Hz
	1 second	10 seconds	1 second	10 seconds	1 second	10 seconds	1 s or 10 s
80 mA	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun
100 mA	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun
120 mA	inadequate stun	>90% unconscious <20% of birds recover within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun
150 mA	inadequate stun	>90% unconscious <20% of birds recover within 40 s	inadequate stun	>90% unconscious <20% of birds recover within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun
200 mA	inadequate stun	>90% unconscious <20% of birds recover within 40 s	inadequate stun	>90% unconscious <20% of birds recover within 40 s	inadequate stun	>85% unconscious Significant recovery within 40 s	inadequate stun
282 mA	>80% unconscious No recovery within 8 s	combination not tested	>80% unconscious No recovery within 8s	combination not tested	combination not tested	combination not tested	inadequate stun

SL3.1b Controlled atmosphere stunning

All the observations made in the section on Controlled Atmosphere Stunning in Part 1 are relevant to broilers.

SL3.1c Low atmosphere pressure stunning

All the observations made in the section on Low Atmospheric Pressure Stunning in Part 1 are relevant to broilers.

SL3.1d Percussive stunning/blunt trauma

Purpose designed percussive stunning devices can be used but the position and angle of the blow may have a critical effect on its success (Raj and O'Callaghan, 2001).

It is possible to deliver a percussive stun by hand. Cors et al. (2015) reports that broilers receiving a blow to the fronto-parietal region of the head using a 32 cm long wooden handle (90 g) displayed convulsions, absence of corneal reflex, respiratory arrest, loss of auditory evoked potentials (AEPs) in the EEG, and died within two minutes of trauma. Pupillary reflex was absent in 9 of 10 birds. They also report the outcomes of 10 broiler breeders which received a blow to the fronto-parietal region of the head using a 40 cm long round metal stick (290 g). Although all 10 birds displayed convulsions, only seven lost their corneal and pupillary reflex. Four birds did not display respiratory arrest, and in three birds, while AEP was reduced, it was not absent. Five of the birds died within 2 minutes of trauma.

This may indicate that broiler breeders are less susceptible to blunt trauma than broilers. Broiler breeders tend to be older than broilers and this may have been the case here. This may lead to the birds having more calcified skulls. Alternatively, this may point to differences in the instrument used to inflict the trauma. The metal stick used to stun broiler breeders had a smaller contact area and was harder than the wooden handle used to stun broilers and so may have caused skull fractures, rather than acceleration of the head, which is necessary to induce concussion. The data presented show that some of the birds stunned with the metal stick sustained fractures to the skull, whereas no fractures are reported for the birds stunned with a wooden handle (Cors et al., 2015). While it is not possible to quantify the force applied to each bird or the exact position of the blunt trauma, it does illustrate that small differences in application may lead to significantly different outcomes across birds.

SL3.2 Laying hens

There is relatively little peer-reviewed literature available regarding the slaughter of laying hens. Outside of emergency killing or humane killing for ill and injured individuals, laying hens are often killed at the end of their peak laying performance at approximately 1 year old. This is in contrast to broilers, which are typically killed at 7 weeks of age. End-of-lay hens (also known as spent hens) may suffer from brittle bones, and are susceptible to injury if caught, transported and shackled for slaughter (Knowles and Wilkins, 1998). Estimates of the number of end-of-lay hens presenting with broken bones varies with breed and with the housing and catching method. The percentage of birds sustaining broken bones may be as high as 30% (Gregory and Wilkins, 1989b). Modern commercial layers may sustain more breakages than heritage lines (8-10% vs 3.5%) (Budgell and Silversides, 2004).

SL3.2a Electrical water-bath

End-of-lay hens tend to have high electrical impedance, meaning that higher voltages are necessary to reach a current suitable for adequate stunning. Hindle et al. (2010) calculated the measured the impedance of hens in an experimental sample and reported impedances of 1,300-5,000 ohms.

Gregory et al. (1991) reported that 99% end of lay hens exposed to water-bath stunning showed cardiac fibrillation when stunned with a sinusoidal 50Hz AC current of more than 110 mA rms. More recently Hindle et al. (2010) working with square wave AC in a single-bird water-bath arrangement produced data suggesting that to achieve an effective stun in 90% of hens, the frequency should not be higher than 50 Hz and current not less than 150 mA rms. This may be compared with broilers and ducks which, under the same conditions, were found to require 125 mA and 150 mA respectively.

SL3.2b Electrical head-only stunning

Head-only stunning produces reversible short duration stuns. Gibson et al. (2016) examined head-only electrical stunning in broilers and end-of-lay hens using standard commercial available electrodes placed on either side of the head spanning the brain. The birds received a 7 s exposure to a 50 Hz AC stunning current of 470 mA (broilers) and 620 mA (hens). The time to return of indicators of consciousness for the hens was significantly shorter than for the broilers (recovery of breathing 24 s (hens) and 33 s (broilers)). It is not clear how much of the variation should be attributed to the difference in current, but the study indicates that hens exposed to head-only stunning might experience even shorter durations of unconsciousness than broilers.

SL3.2c Controlled atmosphere stunning

Gerritzen et al. (2007) provides data suggesting that the conscious responses of hens to carbon dioxide (head shaking, respiratory disruption etc.) may start at higher gas concentrations than in broilers, however there is no indication that hens lose consciousness later than broilers. Apart from this the literature provides no suggestion that controlled atmosphere stunning for hens or broilers should differ.

Turner et al. (2012) reports on trials on use of carbon dioxide for whole house killing of hens for either at end of lay or for disease control. This was carried out in sealed barns into which carbon dioxide was introduced through built-in ducts. EEG evidence indicates that in such a setting, hens may lose consciousness within 2 minutes of carbon dioxide levels reaching 18-20%. Before consciousness is lost, some head-shaking, gasping and clonic muscle contractions may be seen. Unconsciousness is rapidly followed by brain death in approximately 5 minutes.

Submersion in high expansion (300:1 ratio) anoxic foam filled with nitrogen or carbon dioxide induces rapid unconsciousness and death in adult laying hens. Laying hens submerged in nitrogen filled foam demonstrate suppressed EEG activity after 30 s, (suggesting unconsciousness) and an isoelectric EEG was seen after 65 s (McKeegan et al., 2013a). Residual oxygen levels were between 0.33% and 3.0%. Time to loss of consciousness in carbon dioxide filled foam for hens is not given, although McKeegan reports that broilers showed suppressed EEG after 18 s.

SL3.3 Turkeys

In the EU, 76% of turkeys are stunned using electrical water-baths, and 24% using CAS (European Commission, 2012).

SL3.3a Electrical water-bath and head-only stunning currents

There have been few investigations into the water-bath currents required to stun turkeys in an electrical water-bath. Mouchonière et al. (2000) working with 6 kg turkeys tested an AC stun current of 150 mA using frequencies of 50 Hz (5 birds), 300 Hz (30 birds) and 600 Hz (37 birds). Somatosensory evoked potentials (SEPs) were suppressed for all the birds. There was no recovery of SEPs at 50 Hz because all 5 birds experienced cardiac arrest. For the other two conditions SEPs returned at 69 s and 34 s respectively.

Gregory and Wotton (1991), however, had earlier investigated the use of a 50 Hz AC to stun turkeys in a water-bath. Working with 56 birds of average weight 10.6 kg, they tested currents ranging from 120 to 250 mA. Between 50% and 75% of the birds lost somatosensory evoked potentials (SEPs) and there was no indication that the proportion of birds losing SEPs varied with stunning current. The proportion of birds that displayed cardiac fibrillation increased with current from 75% and only reached 100% at 250 mA.

Mouchonière et al. (2000) suggest that this discrepancy between their water-bath results (100% SEP loss and 100% cardiac arrest) with those of Gregory and Wotton (1991) (50 – 75% SEP loss and 75 – 80% ventricular fibrillation) was due to bird size. They support this with the observation that in another unpublished trial where brain activity was not measured, less than 60% of 10 kg male turkeys showed cardiac arrest after stunning in a water-bath using 50 Hz AC and a current of 150 mA.

Gregory and Wotton (1991) report trials into head-only electric stunning using 50 Hz AC currents of 300 and 400 mA. Eight turkeys were stunned using each current. At 400 mA all the turkeys lost SEP whereas at 300 mA only 25% lost SEP. Recovery for both groups was rapid.

Gregory and Wotton (1988) estimated the time to brain death through exsanguination for turkeys to be 64 s. However in light of later work on broilers, this estimate seems to be very conservative. Raj et al. (2006a; 2006c) reported that the EEG of electrically stunned broilers was reduced to 10% of normal power within 20 s of all blood vessels in the neck being severed, whereas Gregory and Wotton (1986) had previously assessed time to brain death to be 60 s.

On the basis of this sparse information EFSA (2012) make the recommendation that turkeys should be stunned in a water-bath using minimum currents of 250 mA at frequencies of less than 200 Hz and using 400 mA at frequencies of between 400 and 1,500 Hz.

SL3.3b Controlled atmosphere stunning

Carbon dioxide is used to stun and kill turkeys in CAS systems. Gerritzen et al. (2006) reports that turkeys lose consciousness at carbon dioxide concentrations between 19% and 25% and that exposure to concentrations of 45% for 13 minutes results in death.

The times to loss of Sensory Evoked Potentials in turkeys exposed to various gas mixtures has been measured by Raj and Gregory (1994), and are outlined in Table SL4 below. The carbon dioxide concentration does not significantly affect time to loss of SEPs.

Table SL4: Times to loss of SEPs for turkeys exposed to various gas mixtures. Data from Raj and Gregory (1994).

Gas mixture	Time to loss of SEPs (range and mean)
90% argon in air	25-61 s, mean 44 s
30% CO ₂ and 60% Ar in air	16-34 s, mean 22 s
49% CO ₂ in air	14-32 s, mean 20 s
65% CO ₂ in air	11-24 s, mean 15 s
86% CO ₂ in air	12-34 s, mean 21 s

SL3.3c Whole house killing

Gerritzen et al. (2007) provide data indicating that the carbon dioxide concentrations at which both conscious responses (e.g. head shaking, respiratory disruption), and unconscious or involuntary reactions (loss of posture, convulsions), do not differ between broilers and turkeys. Loss of posture was observed at 19% carbon dioxide concentration for turkeys, and this occurred after 4 minutes of gradually increasing carbon dioxide concentration.

A trial of whole house euthanasia for turkeys with high expansion carbon dioxide foam is reported by McKeegan et al. (2013a). Suppressed EEG, interpreted as loss of consciousness was observed in as little as 15 s after submersion, but surprisingly, loss of posture was observed at 47 s. Transitional EEG was apparent before submersion in carbon dioxide foam, presumably as a result of a blanket layer of the gas released by bursting bubbles.

SL3.3d Blunt trauma and captive bolt stunning

On-farm euthanasia for small numbers of turkeys can be carried out using blunt trauma, either manually or using a captive bolt gun. Cervical dislocation does not abolish signs of sensibility in turkeys – gasping and the nictitating membrane reflex may continue for some time after cervical dislocation (Erasmus et al., 2010).

Blunt trauma can be applied by delivering a blow perpendicularly to the top of the head, when the head is supported by a hard surface. This has been demonstrated to cause immediate insensibility as assessed by brain-stem reflexes (Erasmus et al., 2010) and abolition of auditory evoked potentials (Cors et al., 2015). Both of these studies report blunt trauma applied by trained people using a variety of implements, each according to standard practice on individual farms (e.g. wooden handle, metal pipe, metal bat). Cors et al. (2015) describes the force required as equal to that 'needed to push a nail into a wooden piece with one strike', although this is difficult to quantify. Cors also notes that the force applied to smaller birds was slightly less, to avoid crushing the skull, although no differences in the effectiveness of blunt trauma are seen across a variety of bird weights (4.9 – 15.7 kg).

Erasmus et al. (2010) reports an investigation into the use of a Zephyr compressed air captive bolt stunner. Erasmus applied the blow perpendicularly to the frontal bone on the midline between the ears and the eyes, directly above the cerebral cortex and reported that that two strikes were required to create insensibility. Unpublished measurements by Lines (2014) indicated that at the air pressure used by Erasmus with this device, a percussive energy of 9.6 J is delivered. We can therefore conclude that 9.6 J was not sufficient percussive energy to stun turkeys. Hewitt (2000) showed that the use of a percussive non-penetrative captive-bolt device, delivering percussive energy of at least 27 J, is effective for on-farm killing of all poultry species.

SL3.4 Ducks

SL3.4a Electrical water-bath stunning

Electrical water-bath stunning is the most common slaughter method used for ducks entering the food chain. However, there is limited research into the welfare and electrical parameters necessary to stun and kill ducks in a water-bath.

Hindle et al. (2010) measured the current passed through individual ducks in an electrical water-bath, and reported that the measured impedance of ducks was 900-2,800 ohms. Inspection of Hindle et al.'s (2010) results suggests that for a 90% chance of achieving a good stun, current should be no less than 140 mA rms at 50 Hz, or 225 mA at 400 Hz. This is corroborated by a variety of other, older papers (e.g. Gregory and Wilkins, 1990). It is particularly important for ducks that the whole head is fully immersed in the electrified water. When only the beak and crop are immersed, disruption of normal brain function is typically less profound and this may be due to the brain receiving a lower proportion of the current that is passing through the whole bird. This has been observed experimentally by Gregory and Wotton (1992) who reported that ducks submerged only as far as the head and beak did not lose brain-stem responses, although they subsequently died as a result of ventricular fibrillation caused by the current passed through the body.

There has been a small amount of research into electrical stunning of ducks at higher frequencies. There is little reason to use high frequencies for ducks since they are less susceptible to blood splash and red wing tips than broilers so the commercial pressure to use low current and high frequencies is less (Gregory and Wilkins, 1990). The exception to this is in the production of foie-gras; where there is some evidence that the livers of force-fed ducks may be affected. Beyessen et al. (2004) found that application of a 150mA AC current at 600 Hz for 4 s did not reliably stun ducks.

SL3.4b Head-only electrical stunning

There is only one known paper reporting head-only stunning in ducks. Beyessen et al. (2003) wetted the head feathers with saline solution and then applied a 50 Hz AC current of 100, 200, 300, 400 and 600 mA across the heads of the ducks using tong mounted spike electrodes. It was concluded that head-only stunning of ducks required a minimum current of 600 mA current and should be followed by bleeding within 15 s to ensure the ducks remained insensible until death.

SL3.4c Controlled atmosphere stunning

When ducks are subjected to gradually increasing carbon dioxide concentrations, they appear to lose consciousness (as assessed by EEG) as the concentration reaches 21%, (Gerritzen et al., 2006) and lose posture at 23-24% carbon dioxide (Gerritzen et al., 2006; 2007). A near iso-electric EEG signal was observed as carbon dioxide concentration reached 43%.

SL3.4d Whole house killing

In carbon dioxide filled foam, ducks lose consciousness very quickly. Assessment of their EEG signal reveals transitional activity as early as 11 s before full submersion, presumably as ducks succumb to the carbon dioxide blanket layer over the foam. Consciousness is lost 1 s after submersion in the foam and all movement ceases 69 s from submersion (McKeegan et al., 2013a). When ducks are submerged in water-based foam filled with atmospheric air, times to unconsciousness, motion cessation and brain death are significantly longer (Benson et al., 2012).

SL3.5 Geese

SL3.5a Controlled atmosphere stunning

In a pair of trials, Gerritzen et al. (2013b) recorded EEG as wild geese were exposed to concentrations of carbon dioxide and argon. In the first trial carbon dioxide was introduced raising the concentration to 80% in 60 s. In the second trial carbon dioxide was added raising the concentration to 40 - 50% over a period of 60 s and then argon was added until the oxygen content of the atmosphere dropped to below 1%. This was achieved in a further 60 s and the final carbon dioxide content was 12 - 15%. The time taken to reach unconsciousness was 50 - 56 s, and did not differ significantly between the treatments.

SL3.5b Other investigations into stunning and killing for geese

A variety of stunning and stun/killing methods for force-fed geese are described by Fernandez et al. (2010). This work describes water-bath stunning (constant current 130 mA; 50 Hz AC), which resulted in 90% of geese apparently dead on exit; two phase CAS, in which geese were submerged in a carbon dioxide/oxygen/nitrogen (40%-30%-30%) mixture for two minutes, followed by 85% carbon dioxide in air for two minutes, resulting in 100% apparently dead birds on exit; and mechanical stunning, using a 6 mm diameter penetrative bolt placed at the midline at the top of the skull (1 cm back from an imaginary line joining the eyes), a treatment which was survived by all geese. 80% of geese subjected to mechanical stunning showed head movements after 'stunning'. All stunning methods were followed by cutting of the neck blood vessels within 10 s. It is not clear how Fernandez et al. (2010) assessed apparent death, but the authors do concede that some of the ducks killed in the same experiment showed head movements on the bleeding rail, having previously been assessed as dead on exiting stunning procedures. These experiments were not designed to measure welfare, but may provide some insight into mortality outcomes of some stunning or stun/kill parameters for geese.

Fernandez et al. (2010) also reference some unpublished results of their own, mentioning that they have been unable to achieve a satisfactory stun for geese with head-only tongs, even when current is up to 1 A 50 Hz AC, but do not give any further details or explanation.

Some non-peer-reviewed papers have assessed the effectiveness of water-bath stunning for geese, and based on their findings, EFSA currently recommend a current of 130 mA rms at 50 Hz AC, although it is not known whether this current produces stunning before inducing cardiac fibrillation in geese (EFSA, 2006).

SL3.6 Guinea fowl

No peer-reviewed literature has been found on the slaughter of guinea fowl. Some recommendations for electrical water-bath stunning of guinea fowl can be found in the Humane Slaughter Association Guidelines for the Electrical Stunning of Poultry, where stunning with at least 100 mA rms per bird at 50 Hz sine wave AC is advised (Humane Slaughter Association, 2015).

SL3.7 Quail

Quail are one of the smallest birds farmed to enter the food chain. There are very few peer-reviewed papers on the stunning and killing of quail. At slaughter, quail are usually processed without being bled, as is the case with many game birds (Gregory et al., 1991). Therefore, it is crucial that the stunning technique used causes death so that there is no possibility of recovery during subsequent processing. Quail are very susceptible to stress. This may mean that stun/kill techniques which minimise handling should be preferred. CAS or LAPS would seem to be the best solution.

SL3.7a Electrical water-bath stunning

Gregory et al. (1991) subjected quail to water-bath stunning with a variety of currents at 50 Hz sine wave AC and 200 Hz square wave pulsed DC. They report that when 50 Hz sinusoidal AC was used, all quails were fibrillated even at the lowest current tested, 45 mA. With a square wave 200 Hz pulsed DC current, all quails were fibrillated when the current was 50 mA, but with currents less than this there was a sharp decline in the proportion of quails experiencing fibrillation.

SL3.7b Controlled atmosphere stunning

Quail exposed to 90% argon in air (2% residual oxygen), or 30% carbon dioxide and 60% argon in air (2% residual oxygen) lose posture after an average of 8 and 9 s respectively. All movements, including spasms, cease within 1 minute, and on removal from the gaseous atmospheres, there is no recovery (Tserveni-Gousi et al., 1999). As with chickens, quail appear to be able to detect the presence of carbon dioxide. Tserveni-Gousi et al. (1999) note that quail showed gasping and head-shaking as soon as they were immersed in the carbon dioxide rich atmosphere, but no behavioural reaction to the induction of unconsciousness was noted with exposure to argon alone. Tserveni-Gousi compared the carcass quality of birds killed using CAS to quail killed using a water-bath (60 mA at 50 Hz AC), and concluded that CAS resulted in fewer broken bones and other carcass defects than electrical water-bath stunning.

SL3.8 Partridges

No peer-reviewed literature on the stunning of partridges has been found. Partridges are bigger than quail, but smaller than pheasants. If they are processed as game birds and not exsanguinated, then like quail, it is imperative that a stun/kill method is used to avoid birds regaining consciousness during processing. It is possible that electrical water-bath stunning may be appropriate, however CAS or LAPS methods may be a safer option as these are stun-to-kill methods.

SL3.9 Pheasants

No peer-reviewed literature on the stunning of pheasants has been found. If they are processed as game birds and not exsanguinated, then like quail, it is imperative that a stun/kill method is used to avoid birds regaining consciousness during processing. It is possible that electrical water-bath stunning may be appropriate, however CAS or LAPS methods may be a safer option as these are stun-to-kill methods.

SL3.10 Pigeons

No peer-reviewed literature on the stunning of pigeons has been found. If they are processed as game birds and not exsanguinated, then like quail, it is imperative that a stun/kill method is used to avoid birds regaining consciousness during processing. Electrical water-bath stunning is unlikely to be an option for these birds because of their size. CAS or LAPS methods may be appropriate.

SL3.11 Ostriches

Ostriches are typically slaughtered for meat at 9-10 months of age, or at 14 months for leather. The primary stunning method is head-only electrical stunning, although mechanical percussive stunning has also been researched as a humane killing method. Ostriches appear to be easily stressed so significant efforts to maintain a calm atmosphere and long lairage times are needed (Hoffman, 2012).

SL3.11a Electrical stunning

Electrical stunning, combined with an effective handling system, can produce an effective and humane stun in ostriches. Ostriches undergo head-only stunning, followed quickly by exsanguination.

Wotton and Sparrey (2002) reported on commercial practice for South African black ostrich slaughter in an abattoir in South Africa. They measured the current passed across the heads of over 400 ostriches and observed the birds afterwards for behavioural signs of unconsciousness. The stunning current was applied for approximately 10 s. The current varied according to the voltage setting used and the impedance of the individual birds. Current varied from less than 100 mA to over 800 mA. Wotton and Sparrey concluded from this observation that a 10 s exposure to a 50 Hz AC stun current of 312 mA should result in unconsciousness for 90% of birds. Ostriches were bled within 60 s of the start of the stun.

A minimum current of 500 mA (50Hz, presumed AC) for 3-6 s was recommended by Lambooij et al. (1999b) to ensure adequate stunning in 90% of ostriches. This recommendation was made on the basis of examination of the EEG signals. It is worth noting that the duration of insensibility reported by Lambooij was only 25 s.

Wotton and Sparrey report that shackling birds while stunning current was flowing allowed ostriches to be safely inverted and hung by their big toes before convulsions started. Hoffman (2012) reports on a padded restraining and stunning box (Divac restraining and stunning box) which rotates 180° to allow for easier and safer shackling but no further references to this device can be found outside of this publication. Hoffman et al. (2009) observes that bleed-out tends to be more efficient, and it appears time to death may be faster when a ventral throat cut is combined with thoracic sticking.

SL3.11b Mechanical stunning

A penetrating captive bolt can be used to stun ostriches, although it is not known whether the stun is caused by concussion, destruction of neural tissue, or bleeding of the brain. EFSA (2006) recommend that the bolt is placed at the crossover point between imaginary lines drawn between the eyes and contralateral ears, or on the crown of the head with the bolt in the direction of the throat. Further parameters are not given. When using bolt stunning, adequate restraint is important, as the clonic spasms which follow make it difficult for the operator to safely handle and bleed the animal.

Lambooij et al. (1999b) reports on an experimental design for an air-pressure mechanical stunning device. A modified nail gun was fitted with two hollow needles, each of which was equipped with holes to allow air to flow through in various directions. Compressed air was injected at 3 bar as the needles penetrated the skull. Lambooij reports that this appeared to cause insensibility for most animals, although further work would be necessary to develop this method as a suitable stunning device.

SL3.12 Emus

Similar to ostriches, emus are ratites, large, flightless birds, farmed for their meat, hide and oil. No peer-reviewed publications have been found relating to the slaughter of emus. It seems likely that emus are slaughtered similarly to ostriches, and the welfare guidelines of various countries and organisations fail to distinguish between ostriches and emus. This does not however necessarily mean that the same stunning parameters are valid for both types of bird. The only reference found to stunning parameters for emus specifically is in the American Veterinary Medical Association's (2016) Guidelines for the Humane Slaughter of Animals, but this appears to be taken from a publication concerned with minimising convulsions to reduce damage to the skin, rather than welfare. Furthermore, no waveform or frequency is specified, making the recommendation meaningless.

SL4. WELFARE CONSIDERATIONS: OVERVIEW

The main slaughter methods applied to poultry in high throughput processing plants are electrical water-bath stunning followed by bleeding, and controlled atmosphere stunning and killing (CAS) using carbon dioxide, nitrogen or argon. The balance of scientific opinion is that controlled atmosphere killing offers the higher standard of welfare.

Low atmospheric pressure stunning and killing (LAPS) is a new technique suitable for large throughput processing plants that may offer higher standards of welfare at slaughter than either the preceding methods. Its use has been extensively researched only for broiler chickens. Currently its use is very limited and it has not yet been approved for use in Europe.

Large scale head-only electrical stunning of poultry is another new approach, however it has received relatively little scientific scrutiny. This complex approach appears to solve some but not all of the problems of the electrical water-bath system for broilers. It may be uniquely suitable for halal slaughter.

Electrical water-bath stunning is widely used for laying hens, broilers, ducks, geese, turkeys, quail and guinea fowl. CAS and LAPS may offer higher welfare at slaughter than the electrical water-bath for all these species and in addition may be suited to partridge, pheasants and pigeons.

Small scale stunning and killing methods for small producers and for killing stock at the end of their economically useful lives commonly include head only electric stunning and percussive stunning. Some mobile electrical water-bath, CAS and LAPS systems also exist that can be moved from farm to farm.

For large scale emergency slaughter due to disease, controlled atmosphere stunning and killing using carbon dioxide filled bins or whole house gas or foam systems have been developed. Whole house killing of laying hens using gas is also recommended on welfare grounds in some countries.

Reported research on ostrich stunning and killing is limited to head only electric stunning and a mechanical technique. It is not clear whether CAS or LAPS have potential to reduce stress at slaughter for ostrich and emu.

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GLOSSARY

Term	Definition
AC	Alternating current.
ACTH	Adrenocorticotrophic hormone.
<i>ad libitum</i>	Usually in conjunction with feed and water, meaning available all the time.
aetiology	The science that deals with the causes or origin of disease and factors which produce or predispose toward a certain disease or disorder.
agonistic	Any social behaviour related to fighting.
anoxia	Absence of oxygen.
anoxic atmosphere	An atmosphere where oxygen is completely absent.
anthelmintics	Medicines used to treat parasitic worm infestations.
antibody	A blood protein produced in response to and counteracting a specific antigen. Antibodies combine chemically with substances which the body recognises as alien, such as bacteria, viruses, and foreign substances in the blood.
antigen	Any substance (e.g. toxin) that causes an immune system to produce antibodies against it.
ascites	The accumulation of fluid in the peritoneal cavity, causing abdominal swelling. Particularly prevalent in fast-growing birds (broilers) whose organ development lags in capacity. More prevalent at higher altitudes.
aversive	A stimulus that an animal avoids, with negative valence (likely to be experienced as unpleasant).
behavioural need	A behaviour which experiments have demonstrated to be very important for the bird to perform. For example, laying hens will work hard for access to a nest as the time of day when they want to lay approaches, thus nesting is a behavioural need.
BGSS	Bristol Gait Scoring System.
binomial distribution	Frequency distribution where only two (mutually exclusive) outcomes are possible, such as better or worse, using or not using a resource.
biosecurity	All measures designed to reduce the risk of harmful biological agents coming onto the farm, into the house or in contact with the birds. May include measures such as air filtration designed to reduce airborne pathogens.
bit	A plastic ring or other plastic structure inserted through both nostrils to prevent the beak fully closing. Designed to prevent damage due to feather pecking
broiler	A chicken bred specifically for meat production.
cardiac or ventricular fibrillation	When the heart quivers instead of pumping due to disorganised electrical activity in the heart.
CAS	Controlled atmosphere stunning.
CC	Conventional cages.

cerebral ischemia	Insufficient blood supply to the brain to meet metabolic demand, leading to cerebral hypoxia and death of brain tissue.
coccidiosis	Coccidiosis is an infectious parasitic disease of the intestinal tract of animals caused by several species of protozoa.
compensatory feed intake	The quantity of feed an animal consumes after a period of feed restriction.
confounding	Confounding occurs when the effects of an experimental treatment are mixed in with the effects of one or more additional factors, resulting in a distortion of the true relationship. Confounding factors can result in an apparent association between treatment and outcome when no real relationship exists.
conspecifics	Other birds in the same enclosure or flock.
corticosterone	A hormone which has raised levels in the blood when birds are aroused. Similar to cortisone in humans it can indicate both positive (excitement) and negative (stress) states. As it is excreted it may be measured in the droppings of commercial flocks to indicate more chronic states.
contra-free loading	Working/foraging for food even when an adequate diet is freely available. Also applies to other resources.
cue	A cue is any feature that an organism (bird) can use as a guide to display a particular behaviour or series of behaviours.
demand experiment	Based on economic consumer demand theory, animals are asked to 'pay a price' to determine how important, for example, access to an enclosed nest site or to a perch is to them. The 'price' is often pushing through doors, which can have altered, weighted resistance.
depopulation/depletion	Removal of the flock of birds from their housing system at the end of the production period.
desnooding	The removal of the fleshy ornamental head appendage of turkeys.
dopamine receptors	Areas in the brain which bind to dopamine, a neurotransmitter associated with mood.
EC	European Commission (the Regulatory Body of the EU).
ectoparasites	Parasites such as mites and lice found on the outside surfaces of the body.
EEG	Electroencephalogram, a measurement of the electrical activity of the brain which can be used as an indication of unconsciousness and brain death.
embryogenesis	The process by which the embryo forms and develops.
endochondral	Any bone that develops in and replaces cartilage by a process of calcification.
endotoxin	A toxin present inside a bacterial cell that is released when it disintegrates.
et al.	A shorthand used to denote several authors (abbreviated form of the Latin <i>et alia</i>) i.e. 'and others'.
EU	European Union (of Member states or countries).
exsanguination	The process of blood loss to a degree sufficient to cause death.
FC	Furnished (enriched or colony) cages.

feed conversion efficiency (FCE)	Weight of productive output (bodyweight or eggs) divided by the amount of feed consumed. Inverse of FCR.
feed conversion ratio (FCR)	The amount of feed consumed divided by output (i.e. weight of eggs or meat). Inverse of FCE.
FHN	Femoral head necrosis.
focal observations	Methods of observing animal behaviour: either recording occurrence of specific (focal) behaviours, or continuously monitoring a given individual's behaviour (the focal animal) for a specific period of time.
foot pad dermatitis (FPD)	Particularly found in meat birds, this is a skin condition of the pads of the feet comprising lesions resulting from contact with wet, abrasive or corrosive litter. The extent of lesions can be measured by automated image analysis at the abattoir.
forbs	Herbaceous flowering plants other than graminoids (grasses, sedges and rushes).
FP	Feather pecking.
FR	Free-range systems.
friable	Litter that is dry and easily separated.
gait score (GS)	Various qualitative systems have been devised to score walking ability on a defined scale, i.e. gait score.
genotype	Breed or strain.
GFP	Gentle feather pecking.
gizzard	A thick-walled, muscular pouch in the lower stomach of many birds that grinds food, often with the aid of ingested stones or grit.
HB	Hockburn (contact dermatitis found on the skin of the caudal (back) part of the hock joint).
HB	Hot blade (method of beak trimming).
H:L ratio	The relative proportion of heterophylls to leucocytes (types of white blood cells involved in immune function) as measured in blood samples, is used as a measure of stress.
helminth	A common type of ectoparasitic worm in poultry.
heritability	A statistic used in breeding and genetics that estimates how much variation in a phenotypic trait in a population is due to genetic variation among individuals in that population. Other causes of measured variation in a trait are characterised as environmental factors.
homeostasis	Maintaining a condition of balance or equilibrium within the body's internal environment, even when faced with external changes.
humerus	Portion of the wing formed of two short bones; it is located between the radius, the ulna and the metacarpus.
hybrid	A cross between two or more pure breeds.
hypercapnia	The presence of excessive amounts of carbon dioxide in the blood.
hypercapnic atmosphere	An atmosphere with elevated partial pressure of carbon dioxide compared to 'normal' atmospheric levels.

hypoxia	A condition in which tissues in the body are deprived of adequate oxygen.
hypoxic atmosphere	An atmosphere with reduced partial oxygen pressure compared to 'normal' atmospheric conditions.
immune function	How well the immune system is functioning to protect the body against disease. Stress may impair immune function.
ingest	Consume, eat.
Inter-quartile range	A statistical measure of "midsread", being the difference between the 25 th and 75 th percentiles.
IP	Injurious pecking.
IR	Infra-red (method of beak trimming).
Isoelectric electroencephalogram (EEG)	Very low or no brain activity, often resulting in brain death.
kurtosis	A measure of whether data are heavy-tailed or light-tailed relative to a normal distribution. (see skew also)
LAPS	Low atmospheric pressure stunning.
locomotory	Activities including walking and running.
LTL	Latency to lie.
mandibulation	Distinctive bouts of rapid bill movements.
meal feeding	An alternative to having feed continuously available (<i>ad libitum</i>), where feed is distributed in several portions during the day with periods when feed is not available in between. For broilers in particular this may enhance digestion and allow periods of undisturbed rest.
meta-analysis	A statistical analysis of a large number of studies that may give more solid evidence than single studies alone or sometimes find new relationships.
metabolism	The chemical processes that occur within a living organism (here, bird) in order to maintain life.
metabolite	An end product of a biochemical reaction in the body.
morphological	The size, shape, and structure of an animal (or body part).
moulting	Shedding of feathers and then re-growing a new set. This may be induced by severely restricting feed, which causes the birds to stop laying eggs. After the moult they lay eggs at an enhanced rate of production.
MT	Multi-tier barn or aviary.
n-3	Also known as omega 3 - in relation to a type of polyunsaturated fatty acid important in the diet for normal health.
NC	Non-cage systems (barns).

necropsy	Post mortem examination.
nociceptors	Specialised peripheral sensory neurons for detecting pain.
operant tasks	Tasks where the bird is trained to do something like key pecking for a feed reward or even to halt an unpleasant sensation such as noise or vibration.
oviposition	Egg laying.
pathogen	An agent that causes infection or disease, e.g. bacteria, viruses.
pathology	The study of diseases and of the changes that they cause.
pDC	Pulsed direct current.
phenotypic	The observable physical or biochemical characteristics of an organism (here, bird), as determined by both genetic makeup and environmental influences.
photoperiod	Period of light. Generally used to describe (the duration of lights on in) a lighting programme. For example, 16L:8D means 16 hours of light and 8 hours of darkness.
physiology	The (study of) normal biological functioning of a bird.
plumage	Overall feather cover and characteristics.
poult	A young fowl, (e.g. turkey, pheasant etc.).
probiotics	Live micro-organisms which, when administered in adequate amounts, confer a health benefit on the host. For example, lactobacilli fed to 'crowd-out' potentially pathogenic gut bacteria.
prospective studies	A prospective study watches for outcomes, such as the development of a disease, during the study period and relates this to other factors such as suspected risk or protection factor(s).
pullet	A young female bird that has not reached sexual maturity (i.e. pre-egg laying).
radiography	Examination of bones using x-rays or similar technology.
retrospective studies	A retrospective study looks backwards and examines exposures to suspected risk or protection factors in relation to an outcome that is established at the start of the study.
RH	Relative humidity.
scotophase	The dark phase in a cycle of light and darkness.
SDS	Sudden death syndrome.
SE (se)	Standard error (of the mean) - a measure of variability of the data from which the mean is derived.
SEP	Somatosensory Evoked Potential, is the electrical response of the brain to stimulation from touch.
serotonin	Serotonin is a neurotransmitter (i.e. a chemical made in the body that affects how nerves in the brain function), which is believed to affect mood. In humans low levels of the chemical have been associated with depression.
SFP	Severe feather pecking.

shear strength	A measure of bone or eggshell strength, determining how well they can resist parallel forces.
skew	Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the centre point. (see also kurtosis)
smothering	Death from lack of air when birds aggregate and pile on top of each other.
social reinstatement	The tendency of a bird to seek company of its companions.
spectacles	Plastic devices fitted to through the nostrils of the beak, which act as forward-facing blinkers preventing the bird from seeing directly forwards. Designed to reduce damage due to feather pecking.
spiking	A common management practice in some countries whereby about halfway through the breeding period some of the older males are replaced with younger males, to maintain fertility levels within breeder flocks.
ST	Single tier barn
stereotypic behaviour	Repetitive actions with no obvious purpose such as big cats in a zoo pacing up and down the sides of their cage. Often seen in barren environments where the animal does not have the materials or facilities to perform the behaviour it wishes to.
stun	Any intentionally induced process which causes loss of consciousness and sensibility without pain.
substrate	Material found on the floor e.g. various types of litter.
Suppressed Electroencephalogram (EEG)	EEG with strongly reduced frequency compared to normal EEG, generally accepted as an indicator of unconsciousness.
T maze	An experimental test where the bird is placed one end of a passageway and when it reaches the junction can chose to move to one two options. Viewed from above, the setup is in the shape of a T. The options are altered to control for left/right bias.
thermoneutral zone	A range of air temperatures where the birds are thermally most comfortable
thinning	(Broilers) A practice where the heavier birds are removed for transport to slaughter leaving the lighter birds to continue to grow for about 10 days longer. This enables more birds to be stocked per house within any regulatory maximum stocking density.
tibia	Strictly, the tibiotarsus, which is the main bone of the leg of a bird, between the femur and tarsometatarsus, formed by the fusion of several tarsal bones with the tibia.
tibial dyschondroplasia (TD)	A disease which disrupts the growth plates on the tibiotarsus, often leading to bowed legs and lameness. Associated with fast growth rates, particularly in meat birds such as broilers and turkeys.
tom	A male adult turkey (breeder).
tonic immobility	Birds commonly 'freeze' when frightened (to reduce the chance of being predated). Experimentally, a similar state can be induced by placing a bird on its side or back. The period of tonic immobility appears to correlate with levels of fear experienced immediately before the test.

Transitional Electroencephalogram (EEG)	Slow wave EEG indicating reduced consciousness, or the onset of unconsciousness.
tryptophan	An amino acid (building block of proteins) that is a precursor to serotonin.
valence	A term used in the study of animal emotion. It describes the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an event, object or situation. It may be accompanied by positive or negative subjective experiences, but these are not amenable to study.
valgus	A deformity in which an anatomical part (e.g. leg bone) is turned outward away from the midline of the body to an abnormal degree.
varus	A deformity in which an anatomical part is turned inward toward the midline of the body to an abnormal degree.
vocalisation	Sound produced by birds such as clucks and squawks, similar to the voice/speech in humans.
Y maze	A variation of a T maze.
zoonotic diseases	Ones which may be transmissible to humans.

APPENDIX A: LITERATURE SEARCHES

The tables in this appendix show the results of the primary and secondary literature searches by farmed bird type.

Laying Hens

Primary Search: (hen* NOT hence* OR “domestic fowl”) AND welfare = 895

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not hens – other farmed birds	175	A comparison of post-mortem findings in broilers dead-on-farm and broilers dead-on-arrival at the abattoir By: Kittelsen, K. E.; Granquist, E. G.; Kolbjornsen, O.; et al. POULTRY SCIENCE Volume: 94 Issue: 11 Pages: 2622-2629 Published: NOV 2015
Not hens – other animals	58	Bones as enrichment for farmed blue foxes (<i>Vulpes lagopus</i>): Interaction with the bones and preference for a cage with the bones By: Koistinen, Tarja; Turunen, Antti; Kiviniemi, Vesa; et al. APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 120 Issue: 1-2 Pages: 108-116 Published: AUG 2009
Paper on consumer attitudes, policy, ethics	24	Consumer Preferences for Improved Hen Housing: Is a Cage a Cage? By: Doyon, Maurice; Bergeron, Stephane; Cranfield, John; et al. CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS-REVUE CANADIENNE D AGROECONOMIE Volume: 64 Published SEP 2016
Paper on fundamental study of genetics, immune function, disease mechanism or stress biology with no immediate welfare relevance	53	Immunological Changes at Point-of-Lay Increase Susceptibility to <i>Salmonella enterica</i> Serovar Enteritidis Infection in Vaccinated Chickens By: Johnston, Claire E.; Hartley, Catherine; Salisbury, Anne-Marie; et al. PLOS ONE Volume: 7 Issue: 10 Article Number: e48195 Published: OCT 25 2012
Paper proposing new technology or method for assessing welfare but no useful results yet	35	Performance of an image analysis processing system for hen tracking in an environmental preference chamber By: Kashiha, Mohammad Amin; Green, Angela R.; Sales, Tatiana Glogerley; et al. POULTRY SCIENCE Volume: 93 Issue: 10 Pages: 2439-2448 Published: OCT 2014
Review/opinion pieces	85	Science-based management of livestock welfare in intensive systems: looking to the future By: Vannier, P.; Michel, V.; Keeling, L. J. REVUE SCIENTIFIQUE ET TECHNIQUE-OFFICE INTERNATIONAL DES EPIZOOTIES Volume: 33 Issue: 1 Pages: 153-160 Published: APR 2014
Paper on production quality, safety or sustainability	19	Quality of Eggs in Different Production Systems By: Yenice, Guler; Kaynar, Ozgur; Ilerturk, Mustafa; et al. CZECH JOURNAL OF FOOD SCIENCES Volume: 34 Issue: 4 Pages: 370-376 Published: 2016
Paper on fundamental nutrition	9	alpha-Linolenic acid- and docosahexaenoic acid-enriched eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans By: Ferrier, Les K.; Caston, Linda J.; Leeson, Steve; et al. GUT Volume: 60 Supplement: 1 Pages: 81-86 Published: APR 2011
Paper on economics with no welfare measures	8	Determinants of economic success in egg production in Germany - here: laying hens kept in aviaries or small-group housing systems By: Campe, Amely; Hoes, Catherina; Koesters, Sarah; et al. LANDBAUFORSCHUNG Volume: 65 Issue: 3-4 Pages: 227-237 Published: DEC 2015
Paper on fundamental study of behaviour or cognition with no immediate welfare relevance	28	Avian maternal response to chick distress By: Edgar, J. L.; Lowe, J. C.; Paul, E. S.; et al. PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES Volume: 278 Issue: 1721 Pages: 3129-3134 Published: OCT 22 2011

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Paper on slaughter	16	Killing of spent laying hens using CO ₂ in poultry barns By: Berg, C.; Yngvesson, J.; Nimmermark, S.; et al. ANIMAL WELFARE Volume: 23 Issue: 4 Pages: 445-457 Published: SEP 2014
Paper on transport	2	Effects of transport distance and the season of the year on death rates among hens and roosters intransport to poultry processing plants in the Czech Republic in the period from 1997 to 2004 By: Voslarova, E.; Janackova, B.; Vitula, F.; et al. VETERINARNI MEDICINA Volume: 52 Issue: 6 Pages: 262-266 Published: JUN 2007
Paper on rare breeds, local varieties or backyard flocks	17	Characterization of two Indian native chicken breeds for production, egg and semen quality, andwelfare traits By: Haunshi, S.; Niranjana, M.; Shanmugam, M.; et al. POULTRY SCIENCE Volume: 90 Issue: 2 Pages: 314-320 Published: FEB 1 2011
Totally irrelevant e.g. people's names	16	Making Better Sense of Animal Disenhancement: A Reply to Henschke By: Schultz-Bergin, Marcus NANOETHICS Volume: 8 Issue: 1 Pages: 101-109 Published: APR 2014
Papers excluded from primary search	545	Papers retained from primary search: 895 – 545 = 350

Laying Hen Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
(hen* NOT hence* OR “domestic fowl”) AND Wellbeing	18	0	
(hen* NOT hence* OR “domestic fowl”) AND Well-being	77	12	
(chick* NOT broiler*) AND welfare	464	7	
“laying hen” AND welfare	253	0	All relevant papers already detected
Search for sub-sets of terms relevant to welfare			
“laying hen” AND health	172	37	Only papers with a welfare focus, not papers on e.g. diet and gut flora
“laying hen” AND (stress* OR fear*)	158	26	Not papers on deliberate induction of heat stress, or papers on dietary supplements with vague aim of improving overall performance
“laying hen” AND (injur* OR cull* OR mortali*)	156	25	Not dietary supplementation or case reports of specific disease outbreaks
“laying hen” AND (density OR space)	177	4	Nearly all relevant papers already detected in previous searches
“laying hen” AND litter OR “laying hen”AND perch* OR “laying hen” AND nest* OR “laying hen” AND enrich*	275	18	Nearly all relevant papers already detected in previous searches. Papers on enriching diets or eggs not included
“laying hen” AND dustbath* or “laying hen” AND dust-bath*	35	0	All relevant papers already detected in previous searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
"laying hen" AND peck* OR "laying hen" AND beak*	147	13	Many relevant papers already detected in previous searches
Papers retained from secondary searches		142	

Total number of papers retained from primary and secondary searches: 350 + 142 = 492

Laying Hen Breeders

Primary Search: (lay* and parent*) AND welfare = 14

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Laying hens not breeders	5	Genomic prediction of survival time in a population of brown laying hens showing cannibalistic behavior By: Alemu, Setegn W.; Calus, Mario P. L.; Muir, William M.; et al. GENETICS SELECTION EVOLUTION Volume: 48 Article Number: 68 Published: SEP 13 2016
Broiler breeders	4	Measuring Motivation for Appetitive Behaviour: Food-Restricted Broiler Breeder Chickens Cross a Water Barrier to Forage in an Area of Wood Shavings without Food By: Dixon, Laura M.; Brocklehurst, Sarah; Sandilands, Vicky; et al. PLOS ONE Volume: 9 Issue: 7 Article Number: e102322 Published: JUL 28 2014
reviews	2	Domestication, selection, behaviour and welfare of animals – genetic mechanisms for rapid responses By: Jensen, P. ANIMAL WELFARE Volume: 19 Supplement: S Pages: 7-9 Published: MAY 2010
Totally irrelevant	2	What can ecological data tell us about reasons for divergence in health status between West Central Scotland and other regions of post-industrial Europe? By: Taulbut, M.; Walsh, D.; Parcell, S.; et al. PUBLIC HEALTH Volume: 127 Issue: 2 Pages: 153-163 Published: FEB 2013
Papers excluded from primary search	13	Papers retained from primary search: 14 – 13 = 1

Layer Breeder Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
"layer breeder" and welfare	1	0	
"layer breeder" and well-being	2	0	
(hen* and parent*) and welfare	28	0	
(Lay* and parent*) and well-being	6	0	
Search for sub-sets of terms relevant to welfare			
(lay* and parent*) and health	264	0	Mostly paediatrics
"layer breeder" and health	4	0	
(lay* and parent*) and (stress* or fear*)	282	0	Mostly paediatrics
"layer breeder" and (stress* or fear*)	7	1	
(lay* and parent*) and injur* OR (lay* and parent*) and cull OR (lay* and parent*) and mortali*	208	1	Mostly ecology of other birds, or ornithology. Some human medicine and some papers on egg quality.
"layer breeder" and injur* OR "layer breeder" and cull OR "layer breeder" and mortali*	8	0	
(lay* and parent*) and (density or space)	814	0	Mostly material science, physical chemistry, physics.

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
"layer breeder" and (density or space)	4	0	All on egg quality
(lay* and parent*) and litter OR (lay* and parent*) " and perch* OR (lay* and parent*) and nest* OR (lay* and parent*) and enrich*	1019	1	Mostly ornithology, ecology, geoscience
"layer breeder" and litter OR "layer breeder" and perch* OR "layer breeder" and nest* OR "layer breeder" and enrich*	2	0	
(lay* and parent*) and (dustbath* or dust-bath*)	0	0	
"layer breeder" and (dustbath* or dust-bath*)	0	0	
(lay* and parent*) and (peck* or beak*)	20	0	
"layer breeder" and (peck* or beak*)	0	0	
Papers retained from secondary searches		3	

Total number of papers retained from primary and secondary searches: 1 + 3 = 4

Broilers

Primary Search: (broiler* NOT “broiler breeder”) AND welfare = 910

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not hens – other farmed birds	97	Influence of genetic strain and access to litter on spatial distribution of 4 strains of laying hens in an aviary system By: Ali, A. B. A.; Campbell, D. L. M.; Karcher, D. M.; et al. POULTRY SCIENCE Volume: 95 Issue: 11 Pages: 2489-2502 Published: NOV 2016
Not hens – other animals	24	Evaluation of an innovative approach for sensory enrichment in zoos: semiochemical stimulation for captive lions (<i>Panthera leo</i>) By: Martinez-Macipe, M.; Lafont-Lecuelle, C.; Manteca, X.; et al. ANIMAL WELFARE Volume: 24 Issue: 4 Pages: 455-461 Published: SEP 2015
Paper on consumer attitudes, policy, ethics	20	Farm openings and their impacts on the attitudes of the visitors towards intensive egg and poultry meat production. Heijne, D (Heijne, D.); Windhorst, HW (Windhorst, H. –W.) WORLD'S POULTRY SCIENCE JOURNAL Volume: 73, Issue: 1, Pages: 105-120. 2017
Paper on fundamental study of genetics, immune function, disease mechanism or stress biology with no immediate welfare relevance	77	Prevalence of histopathological intestinal lesions and enteric pathogens in Dutch commercial broilers with time By: ter Veen, C; de Bruijn, ND ; Dijkman, R; de Wit, JJ AVIAN PATHOLOGY Volume: 46, Issue: 1 Pages: 95-105
Paper proposing new technology or method for assessing welfare but no useful results yet	37	Bioimpedance as a Non-Invasive Method to Evaluate Eggs and Poultry By: Klein, D. R.; Vale, M. M.; Silva, L. P.; et al. BRAZILIAN JOURNAL OF POULTRY SCIENCE Volume: 18 Issue: 2 Pages: 203-207 Published: APR-JUN 2016
Review/opinion pieces	118	Animal welfare challenges for today and tomorrow By: Thaxton, Yvonne Vizzier; Christensen, Karen D.; Mench, Joy A.; et al. POULTRY SCIENCE Volume: 95 Issue: 9 Pages: 2198-2207 Published: SEP 2016
Paper on production quality, safety or sustainability	63	Combining livestock and tree crops to improve sustainability in agriculture: a case study using the Life Cycle Assessment (LCA) approach By: Paolotti, Luisa; Boggia, Antonio; Castellini, Cesare; et al. JOURNAL OF CLEANER PRODUCTION Volume: 131 Pages: 351-363 Published: SEP 10 2016
Paper on fundamental nutrition	21	Alternative feeding strategies and genetics for providing adequate methionine in organic poultry diets with limited use of synthetic amino acids By: Burley, H. K.; Patterson, P. H.; Anderson, K. E. WORLD'S POULTRY SCIENCE JOURNAL Volume: 72 Issue: 1 Pages: 168-177 Published: MAR 2016
Paper on economics with no welfare measures	20	Cost-efficiency of animal welfare in broiler production systems: A pilot study using the WelfareQuality I assessment protocol By: Gocsik, Eva; Brooshooft, Suzanne D.; de Jong, Ingrid C.; et al. AGRICULTURAL SYSTEMS Volume: 146 Pages: 55-69 Published: JUL 2016
Paper on fundamental study of behaviour or cognition with no immediate welfare relevance	14	Vocalisation sound pattern identification in young broiler chickens By: Fontana, I.; Tullo, E.; Scrase, A.; et al. ANIMAL Volume: 10 Issue: 9 Pages: 1567-1574 Published: SEP 2016
Paper on slaughter	71	Effects of light on responses to low atmospheric pressure stunning in broilers By: Martin, J. E.; Christensen, K.; Vizzier-Thaxton, Y.; et al. BRITISH POULTRY SCIENCE Volume: 57 Issue: 5 Pages: 585-600 Published: OCT 2016
Paper on transport	39	Effect of post-hatch transportation duration and parental age on broiler chicken quality, welfare, and productivity By: Jacobs, Leonie; Delezie, Evelyne; Duchateau, Luc; et al. POULTRY SCIENCE Volume: 95 Issue: 9 Pages: 1973-1979 Published: SEP 2016
Paper on rare breeds, local varieties or backyard flocks	17	Blood biochemistry and immune response in Aseel chicken under free range, semi-intensive, and confinement rearing systems By: Rehman, M. S.; Mahmud, A.; Mehmood, S.; et al.

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
		POULTRY SCIENCE Volume: 96 Issue: 1 Pages: 226-233 Published: JAN 2017
Totally irrelevant e.g. people's names	0	
Conference proceedings	39	Improved animal welfare, the right technology and increased business By: Stoier, S.; Larsen, H. D.; Aaslyng, M. D.; et al. Conference: 62nd International Congress of Meat Science and Technology (ICoMST) Location: Bangkok, THAILAND Date: AUG 14-19, 2016 Sponsor(s): Anim Husbandry Assoc Thailand MEAT SCIENCE Volume: 120 Special Issue: SI Pages: 71-77 Published: OCT 2016
Papers excluded from primary search	657	Papers retained from primary search: 910 – 657 = 253

Broiler Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
("meat chicken" OR "meat-type chicken") AND Welfare	11	0	No additional relevant papers
Broiler* NOT "broiler breeder") AND wellbeing	15	0	No additional relevant papers
Broiler* NOT "broiler breeder") AND well-being	64	9	Papers on the effects of prebiotics and antibiotics not included
(Chick* NOT lay*) AND welfare	871	0	No additional relevant papers
Search for sub-sets of terms relevant to welfare			
(broiler* NOT "broiler breeder") AND health	1853	25	Papers on epidemiology, control of disease and dietary supplements not included
(broiler* NOT "broiler breeder") AND (stress* or fear*)	2450	42	Papers relating to meat quality not included. A lot of articles on dietary supplements to combat heat stress not included.
(broiler* NOT "broiler breeder") AND (injur* OR cull* OR mortality*)	2094	17	Papers relating to vaccination or dietary supplementation omitted.
(broiler* NOT "broiler breeder") AND (density OR space)	217	15	Papers relating to production (weight gain) omitted
(broiler* NOT "broiler breeder") AND (enrich* OR nest* OR perch* OR litter)	2463	21	Papers on litter and just production parameters (i.e. growth) omitted.
(broiler* NOT "broiler breeder") AND ("dust bath" OR dustbath*)	1	6	
(broiler* NOT "broiler breeder") AND (peck* OR beak*)	165	5	Mainly to do with specific diet and nutrition studies
(broiler* NOT "broiler breeder") AND "hock burn"	60	0	No additional relevant papers
(broiler* NOT "broiler breeder") AND ("breast blister" OR "breast burn")	15	0	No additional relevant papers
(broiler* NOT "broiler breeder") AND (lame* OR "leg weakness" OR "leg health")	272	16	

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
(broiler* NOT "broiler breeder") AND *dermatitis	310	7	
(broiler* NOT "broiler breeder") AND "tibial dyschondroplasia"	28	4	
(broiler* NOT "broiler breeder") AND (ammonia OR "air quality")	664	6	
(broiler* NOT "broiler breeder") AND pain	76	4	
(broiler* NOT "broiler breeder") AND (thirst* OR hunger OR hungry)	27	0	
(broiler* NOT "broiler breeder") AND light*	946	6	
(broiler* NOT "broiler breeder") AND (aggressi* OR "adverse behaviour" OR "detrimental behaviour")	46	1	
Papers retained from secondary searches		184	

Total number of papers retained from primary and secondary searches: 253 + 184 = 437

Broiler Breeders

Primary Search: “broiler breeder*” AND welfare = 108

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not hens – other farmed birds	6	Providing laying hens in group-housed enriched cages with access to barley silage reduces aggressive and feather-pecking behaviour By: Johannson, S. G.; Raginski, C.; Schwan-Lardner, K.; et al. CANADIAN JOURNAL OF ANIMAL SCIENCE Volume: 96 Issue: 2 Pages: 161-171 Published: JUN 2016
Not hens – other animals	2	Behavioural indicators of hunger in dairy calves By: Vieira, Andreia De Paula; Guesdon, Vanessa; De Passille, Anne Marie; et al. APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 109 Issue: 2-4 Pages: 180-189 Published: FEB 2008
Paper on consumer attitudes, policy, ethics	0	
Paper on fundamental study of genetics, immune function, disease mechanism or stress biology with no immediate welfare relevance	10	Maternal immunization with vaccines containing recombinant NetB toxin partially protects progeny chickens from necrotic enteritis By: Keyburn, Anthony L.; Portela, Ricardo W.; Ford, Mark E.; et al. VETERINARY RESEARCH Volume: 44 Article Number: 108 Published: NOV 13 2013
Paper proposing new technology or method for assessing welfare but no useful results yet	2	MATHEMATICAL WELFARE ASSESSMENT MODEL OF CHICKEN BREEDER FLOCKS By: Bozakova, N.; Popova-Ralcheva, S.; Sredkova, V.; Gerzilov, V.; Atanasova, S.; Atanasov, A.; Sotirov, L.; Georgieva, N. BULGARIAN JOURNAL OF AGRICULTURAL SCIENCE Volume: 18 Issue: 2 Pages: 278-287 Published: APR 2012
Review/opinion pieces	25	Immunosuppressive interactions of viral diseases in poultry By: Umar, S.; Munir, MT; Ahsan, U.; Raza, I.; Chowdhury, MR; Ahmed, Z.; Shah, MAA WORLD'S POULTRY SCIENCE JOURNAL Volume: 73, Issue: 1, Pages: 121-135
Paper on production quality, safety or sustainability	9	Evaluation of egg quality traits in a synthetic coloured broiler female line By: Rajaravindra, K. S.; Rajkumar, U.; Rekha, K.; et al. JOURNAL OF APPLIED ANIMAL RESEARCH Volume: 43 Issue: 1 Pages: 10-14 Published: JAN 2 2015
Paper on fundamental nutrition	0	
Paper on economics with no welfare measures	0	
Paper on fundamental study of behaviour or cognition with no immediate welfare relevance	4	Mating behavior and fertility of broiler breeder males reared on shortened growth cycles By: Moyle, J. R.; Yoho, D. E.; Whipple, S. M.; et al. JOURNAL OF APPLIED POULTRY RESEARCH Volume: 21 Issue: 2 Pages: 272-278 Published: JUN 2012
Paper on slaughter		Electroencephalographic evaluation of the effectiveness of blunt trauma to induce loss of consciousness for on-farm killing of chickens and turkeys By: Cors, J. -C.; Gruber, A. D.; Guenther, R.; et al. POULTRY SCIENCE Volume: 94 Issue: 2 Pages: 147-155 Published: FEB 2015
Paper on transport	0	

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Paper on rare breeds, local varieties or backyard flocks	0	
Totally irrelevant e.g. people's names	0	
Conference proceedings	3	The Wood-Gush legacy: A sociobiology perspective to fertility and welfare in chickens By: Pizzari, Tommaso Conference: Congress of the International-Society-for-Applied-Ethology (ISAE) Location: Vitoria Gasteiz, SPAIN Date: 2014 Sponsor(s): Int Soc Appl Ethol APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 181 Pages: 12-18 Published: AUG 2016
Papers excluded from primary search	61	Papers retained from primary search: 108 – 61 = 47

Broiler Breeder Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
"broiler breeder" AND wellbeing	1	0	No additional relevant papers
"broiler breeder" AND well-being	7	0	No additional relevant papers
Search for sub-sets of terms relevant to welfare			
"broiler breeder" AND health	66	4	Papers on dietary supplements not included
"broiler breeder" AND (stress* or fear*)	181	4	Papers relating to incubation temp and egg quality not included
"broiler breeder" AND (injur* OR cull* OR mortali*)	279	15	Papers relating to vaccination or dietary supplementation omitted.
"broiler breeder" AND (density OR space)	88	0	No additional relevant papers
"broiler breeder" AND (enrich* OR nest* OR perch* OR litter)	130	2	Papers on egg production parameters not included
"broiler breeder" AND ("dust bath" OR dustbath*)	1	0	No additional relevant papers
"broiler breeder" AND (peck* OR beak*)	43	3	Mainly to do with specific diet and nutrition studies
"broiler breeder" AND (thirst* OR hunger OR hungry)	37	0	No additional relevant papers
"broiler breeder" AND light*	109	0	No additional relevant papers
"broiler breeder" AND (aggressi* OR "adverse behaviour" OR "detrimental behaviour")	29	4	
Papers retained from secondary searches		32	

Total number of papers retained from primary and secondary searches: 47 + 32 = 79

Ducks

Primary Search: duck* AND welfare = 60

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not ducks – other species	2	Water quality, growth and stress responses of juvenile barramundi (<i>Lates calcarifer</i> Bloch), reared at four different densities in integrated recirculating aquaculture systems By: Ardiansyah; Fotedar, Ravi AQUACULTURE Volume: 458 Pages: 113-120 Published: MAY 1 2016
Paper on slaughter	6	Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam By: McKeegan, D. E. F.; Reimert, H. G. M.; Hindle, V. A.; et al. POULTRY SCIENCE Volume: 92 Issue: 5 Pages: 1145-1154 Published: MAY 2013
Paper on transport	2	Transport-induced mortality in Pekin ducks transported for slaughter in the Czech Republic By: Voslarova, Eva; Hytychova, Tat'ana; Vecerek, Vladimir; et al. ACTA VETERINARIA BRNO Volume: 85 Issue: 2 Pages: 205-212 Published: 2016
Paper on Wildfowl capture	1	ASSESSMENT OF THE RATES OF INJURY AND MORTALITY IN WATERFOWL CAPTURED WITH FIVE METHODS OF CAPTURE AND TECHNIQUES FOR MINIMIZING RISKS By: O'Brien, Michelle F.; Lee, Rebecca; Cromie, Ruth; et al. JOURNAL OF WILDLIFE DISEASES Volume: 52 Supplement: 2 Pages: S86-S95 Published: APR 2016
Paper proposing new technology or method for assessing welfare but no useful results yet	4	Evaluating Pekin duck walking ability using a treadmill performance test By: Byrd, C. J.; Main, R. P.; Makagon, M. M. POULTRY SCIENCE Volume: 95 Issue: 10 Pages: 2244-2249 Published: OCT 2016
Paper on the control of avian influenza	2	Controlling highly pathogenic avian influenza outbreaks: An epidemiological and economic model analysis By: Backer, J. A.; van Roermund, H. J. W.; Fischer, E. A. J.; et al. PREVENTIVE VETERINARY MEDICINE Volume: 121 Issue: 1-2 Pages: 142-150 Published: SEP 1 2015
Paper on fundamental study of genetics, morphology, immune function, disease mechanism or stress biology with no immediate welfare relevance	4	Duck gait: Relationship to hip angle, bone ash, bone density, and morphology By: Robison, Cara I.; Rice, Meredith; Makagon, Maja M.; et al. POULTRY SCIENCE Volume: 94 Issue: 5 Pages: 1060-1067 Published: MAY 2015
Paper on fundamental study of behaviour or with no immediate welfare relevance	2	When a Duck Initiates Movement, Do Others Follow? Testing Preference in Groups By: Liste, Guiomar; Asher, Lucy; Broom, Donald M. ETHOLOGY Volume: 120 Issue: 12 Pages: 1199-1206 Published: DEC 2014
Paper on production quality / human consumption	2	Influence of housing system on the growth and histological structure of duck muscles By: Damaziak, K.; Michalczuk, M.; Adamek, D.; et al. SOUTH AFRICAN JOURNAL OF ANIMAL SCIENCE Volume: 44 Issue: 2 Pages: 97-109 Published: 2014
A review paper	2	Welfare of ducks in European duck husbandry systems By: Rodenburg, TB; Bracke, MBM; Berk, J; et al. Conference: Workshop on Duck Welfare Location: Wageningen, NETHERLANDS Date: SEP 30-OCT 02, 2004 WORLD'S POULTRY SCIENCE JOURNAL Volume: 61 Issue: 4 Pages: 633-646 Published: DEC 2005
Paper on ecological study	1	Ecological assessment of Cheffa Wetland in the Borkena Valley, northeast Ethiopia: Macroinvertebrate and bird communities By: Getachew, Melaku; Ambelu, Argaw; Tiku, Seid; et al. ECOLOGICAL INDICATORS Volume: 15 Issue: 1 Pages: 63-71 Published: APR 2012
Papers excluded from primary search	28	Papers retained from primary search: 60 – 28 = 32

Duck Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
Anas AND welfare	19	0	No additional relevant papers
waterfowl AND welfare	7	0	No additional relevant papers
duck* AND wellbeing	1	0	Irrelevant article on marine management and environment
duck* AND well-being	11	2	Articles on cognitive identification not included. Articles on ecological studies of ducks not included.
Search for sub-sets of terms relevant to welfare			
duck* AND health	503	3	Articles on control of avian influenza, general immunity not included.
duck* AND (stress* or fear*)	529	12	Papers relating to meat quality not included. Papers on wild duck biology not included. A lot of articles on oxidative stress in duckweed not included.
duck* AND injur* OR duck* AND cull OR duck* AND mortali*	856	3	Mostly papers on wild ducks. Fundamental studies on immunological resistance not included.
(duck* NOT duckweed) AND (density OR space)	847	2	Largely papers on wild ducks.
duck* AND (enrich* OR nest* OR perch* OR litter)	986	2	Mostly papers on wild ducks e.g habitat selection. 2 papers added on nest preferences / laying behaviour in domestic ducks.
duck* AND (waterbath* OR water-bath*)	12	0	All articles on stunning or meat quality.
duck* AND (peck* OR beak* OR bill*)	288	0	Largely on wild duck beak morphology or species name e.g duck-billed.
duck* AND "foie gras"	43	0	Articles on feed conversion, liver quality and production.
duck* AND (force-fed OR force-feed* OR "force fed" OR "force feed")	37	0	Articles on feed conversion, liver quality and production.
Papers retained from secondary searches		24	

Total number of papers retained from primary and secondary searches: 32 + 24 = 56

Geese

Primary Search: (goose OR geese) AND welfare = 15

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not Geese – other species	5	When a Duck Initiates Movement, Do Others Follow? Testing Preference in Groups By: Liste, Guiomar; Asher, Lucy; Broom, Donald M. ETHOLOGY Volume: 120 Issue: 12 Pages: 1199-1206 Published: DEC 2014
Paper on slaughter	2	Killing wild geese with carbon dioxide or a mixture of carbon dioxide and argon By: Gerritzen, M. A.; Reimert, H. G. M.; Lourens, A.; et al. ANIMAL WELFARE Volume: 22 Issue: 1 Pages: 5-12 Published: FEB 2013
Paper on production / meat quality	1	Association analysis of g.68G -> A SNP in CAPN1 gene with carcass and meat quality traits in goose raised in organic dehesa By: Sole, Marina; Negro, Sara; Membrillo, Alberto; et al. ARCHIVES ANIMAL BREEDING Volume: 59 Issue: 4 Pages: 423-428 Published: OCT 17 2016
Review Paper	3	Waterfowl welfare and rearing conditions for meat and foie gras production By: Guemene, D.; Guy, G.; Mirabito, L.; et al. PRODUCTIONS ANIMALES Volume: 20 Issue: 1 Pages: 53-57 Published: FEB 2007
Paper on capture of wildfowl	1	ASSESSMENT OF THE RATES OF INJURY AND MORTALITY IN WATERFOWL CAPTURED WITH FIVE METHODS OF CAPTURE AND TECHNIQUES FOR MINIMIZING RISKS By: O'Brien, Michelle F.; Lee, Rebecca; Cromie, Ruth; et al. JOURNAL OF WILDLIFE DISEASES Volume: 52 Supplement: 2 Pages: S86-S95 Published: APR 2016
Paper on ecological study	1	Ecological assessment of Cheffa Wetland in the Borkena Valley, northeast Ethiopia: Macroinvertebrate and bird communities By: Getachew, Melaku; Ambelu, Argaw; Tiku, Seid; et al. ECOLOGICAL INDICATORS Volume: 15 Issue: 1 Pages: 63-71 Published: APR 2012
Papers excluded from primary search	13	Papers retained from primary search: 15 – 13 = 2

Geese Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
Anser AND welfare	2	0	One already detected, one on carcass quality.
waterfowl AND welfare	7	0	No additional articles detected
(goose OR geese) AND wellbeing	1	0	Paper on microbial flora in intestinal tract with no welfare relevance.
(goose OR geese) AND well-being	6	2	Papers on chronic and acute stressors in captive geese detected.
Search for sub-sets of terms relevant to welfare			
(goose OR geese) AND health	168	0	Largely papers on wild geese and transmission of avian influenza.
(goose OR geese) AND (stress* or fear*)	182	4	Mostly papers on wild geese. One on blood cort around feather gathering and one on stress physiology / behaviour.
(goose OR geese) AND injur* OR (goose OR	363	0	Mostly papers on wild geese.

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
geese) AND cull OR (goose OR geese) AND mortali*			
(goose OR geese) AND (density OR space)	440	0	Mostly relating to wild bird populations.
(goose OR geese) AND (enrich* OR nest* OR litter)	603	0	Mostly ecological studies of wild species.
(goose OR geese) AND (waterbath* OR water-bath)	11	0	Mainly relating to stunning or freezing semen.
(goose OR geese) AND (peck* OR beak* OR bill*)	131	0	Mainly relating to wild birds / morphology.
(goose OR geese) AND "foie gras"	24	0	All relating to meat quality.
(goose OR geese) AND (force-fed OR force-feed* OR "force fed" OR "force feed")	20	1	Mostly relating to meat quality. One on physiological effect of force feeding.
Papers retained from secondary searches		7	

Total number of papers retained from primary and secondary searches: 2 + 7 = 9

Turkeys

Primary Search: welfare AND turkey* OR welfare AND Meleagris NOT fritillaria = 198

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Turkey the country	45	Environmental impacts of coal subsidies in Turkey: A general equilibrium analysis Acar, Sevil; Yeldan, A. Erinc ENERGY POLICY Volume: 90 Pages: 1-15 Published: MAR 2016
Not animal	6	Application of simple and low-cost toxicity tests for ecotoxicological assessment of industrial wastewaters Aydin, Mehmet Emin; Aydin, Senar; Tongur, Sueheyla; et al. ENVIRONMENTAL TECHNOLOGY Volume: 36 Issue: 22 Pages: 2825-2834 Published: NOV 17 2015
Consumer attitudes, policy, ethics	7	Farm openings and their impacts on the attitudes of the visitors towards intensive egg and poultry meat production Heijne, D.; Windhorst, H. –W. WORLD'S POULTRY SCIENCE JOURNAL Volume: 73 Issue: 1 Pages: 105-120 Published: MAR 2017
Review/opinion	11	Unexpected consequences of genetic selection in broilers and turkeys: problems and solutions Hocking, P. M. BRITISH POULTRY SCIENCE Volume: 55 Issue: 1 Pages: 1-12 Published: JAN 2 2014
Fundamental study on genetics, immune function, disease mechanism or stress biology with no immediate welfare relevance	8	Effects of genotype on hematological and serum biochemical responses of turkey hens to stress Damaziak, Krzysztof; Michalczuk, Monika; Zdanowska-Sasiadek, Zaneta; et al. ARCHIVES ANIMAL BREEDING Volume: 60 Issue: 1 Pages: 9-17 Published: JAN 30 2017
Not turkeys	70 (lots of papers on broiler chickens)	High dietary levels of biotin and zinc to improve health of foot pads in broilers exposed experimentally to litter with critical moisture content Abd El-Wahab, A.; Radko, D.; Kamphues, J. POULTRY SCIENCE Volume: 92 Issue: 7 Pages: 1774-1782 Published: JUL 2013
Conference proceedings	2	Tibial dyschondroplasia – tools, new insights and future prospects Pines, M; Hasdai, A; Monsonego-Ornan, E Conference: 22 nd World Poultry Congress Location: Istanbul, TURKEY Date: JUN 08-13, 2004 WORLD'S POULTRY SCIENCE JOURNAL Volume: 61 Issue: 2 Pages: 285-297 Published: JUN 2005
Transport	5	Catching and crating turkeys: Effects on carcass damage, heart rate, and other welfare parameters Prescott, NB; Berry, PS; Haslam, S; et al. JOURNAL OF APPLIED POULTRY RESEARCH Volume: 9 Issue: 3 Pages: 424-432 Published: FAL 2000
Slaughter	12	Electroencephalographic evaluation of the effectiveness of blunt trauma to induce loss of consciousness for on-farm killing of chickens and turkeys Cors, J. –C.; Gruber, A. D.; Guenther, R.; et al. POULTRY SCIENCE Volume: 94 Issue: 2 Pages: 147-155 Published: FEB 2015
New technology or methods for assessing welfare but no useful results yet	5	Prevalence of skin lesions in turkeys at slaughter Allain, V.; Huonnic, D.; Rouina, M.; et al. BRITISH POULTRY SCIENCE Volume: 54 Issue: 1 Pages: 33-41 Published: FEB 1 2013
Paper on nutrition/diet with no welfare implications	1	Influence of feed form and corn particle size on nutrient digestibility and energy utilization by young turkeys Favero, Andre; Maiorka, Alex; Fischer da Silva, Ana Vitoria; et al. REVISTA BRASILEIRA DE ZOOTECNIA-BRAZILIAN JOURNAL OF ANIMAL SCIENCE Volume: 41 Issue: 1 Pages: 86-90 Published: JAN 2012
Papers excluded from primary search	174	Papers retained from primary search: 198 – 174 = 24

Turkey Secondary Searches

Search terms for synonyms of species or welfare	Hits	Refined By	Additional Papers Included
health AND turkey* OR health AND Meleagris NOT fritillaria	5418	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 454	7
stress AND turkey* OR stress AND Meleagris NOT fritillaria	1962	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 294	5
fear AND turkey* OR fear AND Meleagris NOT fritillaria	144		0
injur* AND turkey* OR injur* AND Meleagris NOT fritillaria	903	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 55	2
cull* AND turkey* OR cull* AND Meleagris NOT fritillaria	60		1
mortali* AND turkey* OR mortali* AND Meleagris NOT fritillaria	2173	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 661	14
density* AND turkey* OR density* AND Meleagris NOT fritillaria	1904	Included: Veterinary sciences; agriculture dairy animal science; biology; zoology (behavioural sciences not an option) 298	4
space* AND turkey* OR space* AND Meleagris NOT fritillaria	997	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 112	1
litter* AND turkey* OR litter* AND Meleagris NOT fritillaria	442	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 202	18
perch* AND turkey* OR perch* AND Meleagris NOT fritillaria	62		0
nest* AND turkey* OR nest* AND Meleagris NOT fritillaria	479	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 191	0
enrich* AND turkey* OR enrich* AND Meleagris NOT fritillaria	1036	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 91	0

Search terms for synonyms of species or welfare	Hits	Refined By	Additional Papers Included
dust-bath* AND turkey* OR dust-bath* AND Meleagris NOT fritillaria OR dustbath* AND turkey* OR dustbath* AND Meleagris NOT fritillaria			0
peck* AND turkey* OR peck* AND Meleagris NOT fritillaria OR beak* AND turkey* OR beak* AND Meleagris NOT fritillaria	81		2
lame* AND turkey* OR lame* AND Meleagris NOT fritillaria OR foot* AND turkey* OR foot* AND Meleagris NOT fritillaria OR derm* AND turkey* OR derm* AND Meleagris NOT fritillaria OR hock* AND turkey* OR hock* AND Meleagris NOT fritillaria OR leg* AND turkey* OR leg* AND Meleagris NOT fritillaria	2538	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 641	8
semen* AND turkey* OR semen* AND Meleagris NOT fritillaria OR insemin* AND turkey* OR insemin* AND Meleagris NOT fritillaria	285	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 225	0
handl* AND turkey* OR handl* AND Meleagris NOT fritillaria	330	Included: Veterinary sciences; agriculture dairy animal science; behavioural sciences; biology; zoology 39	0
Papers retained from secondary searches			62

Total number of papers retained from primary and secondary searches: 24 + 62 = 86

Guinea fowl

Primary Search: welfare AND guineafowl* OR welfare AND “guinea fowl*” OR welfare AND numida* OR welfare AND guttera* OR welfare AND agelastes* OR welfare AND acryllium* = 4

Primary reason for exclusion	Number excluded	Example of Paper Excluded for Each Reason
Review of poultry nutrition and production	1	Poultry nutrition for economic egg and meat production: A review By: Mandal, AB; Elangovan, AV; Tyagi, PK INDIAN JOURNAL OF ANIMAL SCIENCES Volume: 75 Issue: 10 Pages: 1215-1226 Published: OCT 2005
Paper on broiler chickens	1	The effects of selective breeding on the architectural properties of the pelvic limb in broiler chickens: a comparative study across modern and ancestral populations Paxton, Heather; Anthony, Nicolas B.; Corr, Sandra A.; et al. JOURNAL OF ANATOMY Volume: 217 Issue: 2 Pages: 153-166 Published: AUG 2010
Review of disease	2	Avian adenoviruses McFerran, JB; Smyth, JA REVUE SCIENTIFIQUE ET TECHNIQUE DE L'OFFICE INTERNATIONAL DES EPIZOOTIES Volume: 19 Issue: 2 Pages: 589-601 Published: AUG 2000
Papers excluded from primary search	4	Papers retained from primary search: 4 – 4 = 0

Guinea Fowl Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
wellbeing* AND guineafowl* OR wellbeing* AND “guinea fowl*” OR wellbeing* AND numida* OR wellbeing* AND guttera* OR wellbeing* AND agelastes* OR wellbeing* AND acryllium* OR well-being* AND guineafowl* OR well-being* AND “guinea fowl*” OR well-being* AND numida* OR well-being* AND guttera* OR well-being* AND agelastes* OR well-being* AND acryllium*	0	0
behav* AND guineafowl* OR behav* AND “guinea fowl*” OR behav* AND numida* OR behav* AND guttera* OR behav* AND agelastes* OR behav* AND acryllium*	29	1
health* AND guineafowl* OR health* AND “guinea fowl*” OR health* AND numida* OR health* AND guttera* OR health* AND agelastes* OR health* AND acryllium*	36	1
fear* AND guineafowl* OR fear* AND “guinea fowl*” OR fear* AND numida* OR fear* AND guttera* OR fear* AND agelastes* OR fear* AND acryllium* OR stress* AND guineafowl* OR stress* AND “guinea fowl*” OR stress* AND numida* OR stress* AND guttera* OR stress* AND agelastes* OR stress* AND acryllium*	15	0
injur* AND guineafowl* OR injur* AND “guinea fowl*” OR injur* AND numida* OR injur* AND guttera* OR injur* AND agelastes* OR injur* AND acryllium* OR cull* AND guineafowl* OR cull* AND “guinea fowl*” OR cull* AND numida* OR cull* AND guttera* OR cull* AND agelastes* OR cull* AND acryllium* OR mortali* AND guineafowl* OR mortali* AND “guinea fowl*” OR mortali* AND numida* OR mortali* AND guttera* OR mortali* AND agelastes* OR mortali* AND acryllium*	37	1
density* AND guineafowl* OR density* AND “guinea fowl*” OR density* AND numida* OR density* AND guttera* OR density* AND agelastes* OR density* AND acryllium* OR space* AND guineafowl* OR space* AND “guinea fowl*” OR space* AND numida* OR space* AND guttera* OR space* AND agelastes* OR space* AND acryllium*	24	1
litter* AND guineafowl* OR litter* AND “guinea fowl*” OR litter* AND numida* OR litter* AND guttera* OR litter* AND agelastes* OR litter* AND acryllium* OR perch* AND guineafowl* OR perch* AND “guinea fowl*” OR perch* AND numida* OR perch* AND guttera* OR perch* AND agelastes* OR perch* AND acryllium* OR nest* AND guineafowl* OR nest* AND “guinea	14	0

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
fowl* OR nest* AND numida* OR nest* AND guttera* OR nest* AND agelastes* OR nest* AND acryllium* OR enrich* AND guineafowl* OR enrich* AND "guinea fowl*" OR enrich* AND numida* OR enrich* AND guttera* OR enrich* AND agelastes* OR enrich* AND acryllium*		
dust-bath* AND guineafowl* OR dust-bath* AND "guinea fowl*" OR dust-bath* AND numida* OR dust-bath* AND guttera* OR dust-bath* AND agelastes* OR dust-bath* AND acryllium* OR dustbath* AND guineafowl* OR dustbath* AND "guinea fowl*" OR dustbath* AND numida* OR dustbath* AND guttera* OR dustbath* AND agelastes* OR dustbath* AND acryllium*	0	0
peck* AND guineafowl* OR peck* AND "guinea fowl*" OR peck* AND numida* OR peck* AND guttera* OR peck* AND agelastes* OR peck* AND acryllium* OR beak* AND guineafowl* OR beak* AND "guinea fowl*" OR beak* AND numida* OR beak* AND guttera* OR beak* AND agelastes* OR beak* AND acryllium*	1	0
handl* AND guineafowl* OR handl* AND "guinea fowl*" OR handl* AND numida* OR handl* AND guttera* OR handl* AND agelastes* OR handl* AND acryllium*	4	0
hous* AND guineafowl* OR hous* AND "guinea fowl*" OR hous* AND numida* OR hous* AND guttera* OR hous* AND agelastes* OR hous* AND acryllium*	21	0
temp* AND guineafowl* OR temp* AND "guinea fowl*" OR temp* AND numida* OR temp* AND guttera* OR temp* AND agelastes* OR temp* AND acryllium*	21	0
Papers retained from secondary searches		4

Total number of papers from primary and secondary searches: 0 + 4 = 4

Pheasants

Primary Search: welfare AND pheasant* OR welfare AND phasianus* = 8

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Fundamental study of disease/treatment efficacy	1	Safety Evaluation of Lasalocid Use in Chinese Ring-Necked Pheasants (<i>Phasianus colchicus</i>) By: Dzikamunhenga, R. S.; Wilberts, B.; Yaeger, M.; et al. AVIAN DISEASES Volume: 57 Issue: 2 Pages: 188-191 Published: JUN 2013
Not pheasants	1	Changes in Selected Biochemical Indices Resulting from Various Pre-sampling Handling Techniques in Broilers By: Chloupek, Petr; Bedanova, Iveta; Chloupek, Jan; et al. ACTA VETERINARIA SCANDINAVICA Volume: 53 Article Number: 31 Published: MAY 13 2011
Fundamental study of technology/technique	1	A 'feather-trap' for collecting DNA samples from birds By: Maurer, Golo; Beck, Nadeena; Double, Michael C. MOLECULAR ECOLOGY RESOURCES Volume: 10 Issue: 1 Pages: 129-134 Published: JAN 2010
Review/opinion	1	Terrestrial carnivores and human food production: impact and management By: Baker, Philip J.; Boitani, Luigi; Harris, Stephen; et al. Conference: Mammal-Society Autumn Symposium held at the Zoological-Society-of-London Location: London, ENGLAND Date: NOV 25-26, 2005 Sponsor(s): Mammal Soc; Zool Soc London MAMMAL REVIEW Volume: 38 Issue: 2-3 Pages: 123-166 Published: APR-JUL 2008
Transport	1	Effects of transport stress and floor space reduction on selected biochemical indices in common pheasant (<i>Phasianus colchicus</i>) By: Suchy, P.; Bedanova, Iveta; Vecerek, V.; et al. ARCHIV FUR GEFLUGELKUNDE Volume: 71 Issue: 2 Pages: 56-61 Published: APR 2007
Papers excluded from primary search	5	Papers retained from primary search: 8 – 5 = 3

Pheasant Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
behav* AND pheasant* OR behav* AND phasianus*	111	6
well-being* AND pheasant* OR well-being* AND phasianus* OR wellbeing* AND pheasant* OR wellbeing* AND phasianus*	0	0
health* AND pheasant* OR health* AND phasianus*	50	0
stress* AND pheasant* OR stress* AND phasianus* OR fear* AND pheasant* OR fear* AND phasianus*	32	1
injur* AND pheasant* OR injur* AND phasianus* OR cull* AND pheasant* OR cull* AND phasianus* OR mortali* AND pheasant* OR mortali* AND phasianus*	99	0
density* AND pheasant* OR density* AND phasianus* OR space* AND pheasant* OR space* AND phasianus*	93	0
litter* AND pheasant* OR litter* AND phasianus* OR perch* AND pheasant* OR perch* AND phasianus* OR nest* AND pheasant* OR nest* AND phasianus* OR enrich* AND pheasant* OR enrich* AND phasianus*	98	0
dust-bath* AND pheasant* OR dust-bath* AND phasianus* OR dustbath* AND pheasant* OR dustbath* AND phasianus*	0	0

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
peck* AND pheasant* OR peck* AND phasianus* OR beak* AND pheasant* OR beak* AND phasianus*	16	0
sight* AND pheasant* OR sight* AND phasianus* OR eye* AND pheasant* OR eye* AND phasianus* OR goggl* AND pheasant* OR goggl* AND phasianus*	29	0
handl* AND pheasant* OR handl* AND phasianus*	9	
hous* AND pheasant* OR hous* AND phasianus* OR pen* AND pheasant* OR pen* AND phasianus*	127	0
Papers retained from secondary searches		7

Total number of papers retained from primary and secondary searches: 3 + 7 = 10

Partridges

Primary Search: welfare AND partridge* OR welfare AND alectoils* OR welfare AND alectoris* OR welfare AND perdix*= 8

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Not Partridge – chickens	2	WELFARE LEVELS IN HERITAGE BREED VS. COMMERCIAL LAYING HENS IN THE LITTER SYSTEM Sosnowka-Czajka, Ewa; Herbut, Eugeniusz; Skomorucha, Iwona; et al. ANNALS OF ANIMAL SCIENCE Volume: 11 Issue: 4 Pages: 585-595 Published: 2011)
Paper on Fundamental stressphysiology	1	Corticosterone in feathers is a long-term, integrated measure of avian stress physiology Bortolotti, G. R.; Marchant, T. A.; Blas, J.; et al. FUNCTIONAL ECOLOGY Volume: 22 Issue: 3 Pages: 494-500 Published: JUN 2008)
Papers excluded from primary search	3	Papers retained from primary search: 8 – 3 = 5

Partridge Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
behav* AND partridge* OR behav* AND alectoils* OR behav* AND alectoris* OR behav* AND perdix*)	145	7
wellbeing AND partridge* OR wellbeing AND alectoils* OR wellbeing AND alectoris* OR wellbeing AND perdix*	0	0
well-being AND partridge* OR well-being AND alectoils* OR well-being AND alectoris* OR well-being AND perdix*)	1	0
health AND partridge* OR health AND alectoils* OR health AND alectoris* OR health AND perdix*	36	1
stess AND partridge* OR stress AND alectoils* OR stress AND alectoris* OR stress AND perdix*	88	2
fear AND partridge* OR fear AND alectoils* OR fear AND alectoris* OR fear AND perdix*	8	0
injur* AND partridge* OR injur* AND alectoils* OR injur* AND alectoris* OR injur* AND perdix*	8	0
cull* AND partridge* OR cull* AND alectoils* OR cull* AND alectoris* OR cull* AND perdix*	6	0
mortali* AND partridge* OR mortali* AND alectoils* OR mortali* AND alectoris* OR mortali* AND perdix*	109	3
density* AND partridge* OR density* AND alectoils* OR density* AND alectoris* OR density* AND perdix*)	118	0
space* AND partridge* OR space* AND alectoils* OR space* AND alectoris* OR space* AND perdix*	15	1
litter* AND partridge* OR litter* AND alectoils* OR litter* AND alectoris* OR litter* AND perdix	11	1
perch* AND partridge* OR perch* AND alectoils* OR perch* AND alectoris* OR perch* AND perdix*	5	0
nest* AND partridge* OR nest* AND alectoils* OR nest* AND alectoris* OR nest* AND perdix*	98	0

Search terms for synonyms of species or welfare	Hits	Additional Papers Included
enrich* AND partridge* OR enrich* AND alectoils* OR enrich* AND alectoris* OR enrich* AND perdix*)	18	0
dust-bath* AND partridge* OR dust-bath* AND alectoils* OR dust-bath* AND alectoris* OR dust-bath* AND perdix*	0	0
dustbath* AND partridge* OR dustbath* AND alectoils* OR dustbath* AND alectoris* OR dustbath* AND perdix*)	2	0
peck* AND partridge* OR peck* AND alectoils* OR peck* AND alectoris* OR peck* AND perdix*	7	2
beak* AND partridge* OR beak* AND alectoils* OR beak* AND alectoris* OR beak* AND perdix*	9	1
diet* AND partridge* OR diet* AND alectoils* OR diet* AND alectoris* OR diet* AND perdix*	117	5
light* AND partridge* OR light* AND alectoils* OR light* AND alectoris* OR light* AND perdix*	48	1
pair* AND partridge* OR pair* AND alectoils* OR pair* AND alectoris* OR pair* AND perdix*	93	1
handl* AND partridge* OR handl* AND alectoils* OR handl* AND alectoris* OR handl* AND perdix*	11	0
hous* AND partridge* OR hous* AND alectoils* OR hous* AND alectoris* OR hous* AND perdix*)	47	0
Papers retained from secondary searches		25

Total number of papers retained from primary and secondary searches: 5 + 25 = 30

Pigeons

Primary Search: [(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND welfare]=23

Primary reason for exclusion	Number excluded	Example of paper excluded for each reason
Not pigeon- other farmed birds	10	Feed-restricted broiler breeders: State-dependent learning as a novel welfare assessment tool to evaluate their hunger state? By: Buckley, Louise Anne; Sandilands, Victoria; Hocking, Paul Morison; et al. APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 165 Pages: 124-132 Published: APR 2015
Not pigeon- other animals	7	Mountain chickadees return to their post-natal dispersal settlements following long-term captivity By: Branch, Carrie L.; Kozlovsky, Dovid Y.; Croston, Rebecca; et al. BEHAVIOUR Volume: 153 Issue: 5 Pages: 551-567 Published: 2016
Paper on fundamental cognition or behaviour with no immediate welfare relevance	1	The ALDB box: Automatic testing of cognitive performance in groups of aviary-housed pigeons By: Huber, Ludwig; Heise, Nils; Zeman, Christopher; et al. BEHAVIOR RESEARCH METHODS Volume: 47 Issue: 1 Pages: 162-171 Published: MAR 2015
Feral pigeon control	2	Feral pigeon control and welfare By: Oxley, J. A. VETERINARY RECORD Volume: 173 Issue: 7 Published: AUG 17 2013
Paper on extreme morphology	2	Variations in the morphology, distribution, and arrangement of feathers in domesticated birds By: Bartels, T JOURNAL OF EXPERIMENTAL ZOOLOGY PART B-MOLECULAR AND DEVELOPMENTAL EVOLUTION Volume: 298B Issue: 1 Pages: 91-108 Published: AUG 15 2003
Racing pigeon transport	1	Transport of racing pigeons and animal welfare By: Gerald, K. DEUTSCHE TIERARZTLICHE WOCHENSCHRIFT Volume: 114 Issue: 3 Pages: 114-115 Published: MAR 2007
Papers excluded from primary search	23	Papers retained from primary search: 23 – 23 = 0

Pigeon Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND (wellbeing OR well-being)	1	0	Avian Influenza paper
Further-restricted search for sub-set of terms relevant to welfare			
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND (racing OR homing)	804	0	Mostly navigation studies and factors affecting homing performance, health
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND health	203	0	Mostly role of wild/feral pigeons in zoonoses or diseases of farmed animals
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND (perch* OR nest* OR enrich* OR litter)	428	4	4 papers using a form of enrichment as part of experimental design. Others mostly wild/feral pigeon nesting or perching deterrents
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND (dustbath* or dust-bath*)	1	0	Other species
(pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed)) AND (injur* OR cull* OR mortali*)	216	0	Mostly wild/feral pigeons

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
Papers retained from secondary searches		4	

Total number of papers retained from primary and secondary searches: $1 + 4 = 5$

Quail

Primary Search: [(quail* OR coturnix) AND welfare] = 83 results

Primary reason for exclusion	Number excluded	Example of paper excluded for each reason
Not quail- other farmed birds	31	Stress and reactivity in three Italian chicken breeds By: Ferrante, Valentina; Mugnai, Cecilia; Ferrari, Lorenzo; et al. ITALIAN JOURNAL OF ANIMAL SCIENCE Volume: 15 Issue: 2 Pages: 303-309 Published: 2016
Not quail- other animals	5	He's getting under my skin! Comparing the sensitivity and specificity of dermal vs subcuticular lesions as a measure of aggression in mice By: Gaskill, Brianna N.; Stottler, Aurora; Pritchett-Corning, Kathleen R.; et al. APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 183 Pages: 77-85 Published: OCT 2016
Paper on transport	1	The effects of transportation stress on Japanese quail (<i>Coturnix Coturnix japonica</i>) fed corn-based diet in comparison with wheat-based diet supplemented with xylanase and phytase By: Hamzekolaei, M. H. Mehraei; Moghaddam, A. K. Zamani; Tohidifar, S. S.; et al. JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION Volume: 100 Issue: 4 Pages: 618-622 Published: AUG 2016
Review paper	5	Early experiences matter: a review of the effects of prenatal environment on offspring characteristics in poultry By: Dixon, L. M.; Sparks, N. H. C.; Rutherford, K. M. D. POULTRY SCIENCE Volume: 95 Issue: 3 Pages: 489-499 Published: MAR 2016
Paper validating welfare assessment method but no useful results relevant to welfare	1	Effects of diet, time since defecation, and drying process of the droppings on corticosterone metabolite measurements in Japanese quail By: Pellegrini, S.; Busso, J. M.; Leche, A.; et al. POULTRY SCIENCE Volume: 94 Issue: 5 Pages: 1068-1074 Published: MAY 2015
Paper on fundamental study of genetics, immune function, disease mechanisms or stress with no immediate welfare relevance	4	A medium density genetic map and QTL for behavioral and production traits in Japanese quail By: Recoquillay, Julien; Pitel, Frederique; Arnould, Cecile; et al. BMC GENOMICS Volume: 16 Article Number: 10 Published: JAN 22 2015
Paper on fundamental nutrition	1	Effects of dietary chromium picolinate supplementation on serum and tissue mineral contents of laying Japanese quails By: Sahin, K; Sahin, N; Kucuk, O JOURNAL OF TRACE ELEMENTS IN EXPERIMENTAL MEDICINE Volume: 15 Issue: 3 Pages: 163-169 Published: 2002
Paper on fundamental cognition or behaviour with no immediate welfare relevance	11	Effect of one week of stress on emotional reactivity and learning and memory performances in Japanese quail By: Calandreau, Ludovic; Bertin, Aline; Boissy, Alain; et al. BEHAVIOURAL BRAIN RESEARCH Volume: 217 Issue: 1 Pages: 104-110 Published: FEB 2 2011
Totally irrelevant	4	Review of Laboratory-Based Terrestrial Bioaccumulation Assessment Approaches for Organic Chemicals: Current Status and Future Possibilities By: Hoke, Robert; Huggett, Duane; Brasfield, Sandra; et al. INTEGRATED ENVIRONMENTAL ASSESSMENT AND MANAGEMENT Volume: 12 Issue: 1 Pages: 109-122 Published: JAN 2016
Papers excluded from primary search	63	Papers retained from primary search: 83 – 63 = 20

Quail Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
(quail* OR coturnix) AND wellbeing	3	0	
(quail* OR coturnix) AND well-being	7	0	
Further-restricted search for sub-set of terms relevant to welfare			
(quail* OR coturnix) AND health	207	0	1 relevant paper which was a duplicate
(quail* OR coturnix) AND (stress* OR fear*)	741	0	Several relevant papers which were duplicates, others on fundamental stress biology
(quail* OR coturnix) AND (density OR space)	519	0	2 relevant papers which were duplicates
(quail* OR coturnix) AND (injur* OR cull* OR mortali*)	371	0	Several relevant papers which were duplicates, others on laboratory lines of quail
quail AND litter OR quail AND perch* OR quail AND nest* OR quail AND enrich*	470	0	Several relevant papers which were duplicates, others on lab quail
quail AND dustbath* OR quail AND dust-bath*	5	1	1 additional paper with several enrichments tested
quail and peck* OR quail and beak*	112	2	2 papers on effects of beak trimming
Papers retained from secondary searches		3	

Total number of papers retained from primary and secondary searches: 20 + 3 = 23

Ostriches

Primary Search: ostrich AND welfare = 25

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Transport or slaughter	6	Effects of pre-transport nutrient supplementation and transport duration on the post-transport blood biochemistry, bodyweight and welfare of ostriches By: Bejaei, M.; Bennett, D. C.; Schaefer, A. L.; et al. ANIMAL WELFARE Volume: 23 Issue: 2 Pages: 209-217 Published: MAY 2014
Other animals	6	The effects of selective breeding on the architectural properties of the pelvic limb in broiler chickens: a comparative study across modern and ancestral populations By: Paxton, Heather; Anthony, Nicolas B.; Corr, Sandra A.; JOURNAL OF ANATOMY Volume: 217 Issue: 2 Pages: 153-166 Published: AUG 2010
Reviews	3	Strengths and weaknesses of meat inspection as a contribution to animal health and welfare surveillance By: Staerk, K. D. C.; Alonso, S.; Dadios, N.; et al.
Papers excluded from primary search	16	Papers retained from primary search: 25 – 16 = 9

Ostrich secondary searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
Struthio AND welfare	19	0	No additional papers detected
Search for sub-sets of terms relevant to welfare			
ostrich AND health*	122	9	Papers on health properties of ostrich meat not included. Papers on basic biochemistry, physiology and immune function not included
ostrich AND (stress* OR fear*)	60	4	Papers on mechanical stress (to egg shells or feet) not included
ostrich AND injur* OR ostrich AND cull OR ostrich AND mortali*	81	3	Injuries to people caused by ostriches not included, embryonic mortality not included
ostrich AND (density OR space)	91	1	Two papers on bone density added to health
ostrich AND litter OR ostrich AND perch* OR ostrich AND nest* OR ostrich AND enrich*	50	3	
ostrich AND dustbath* OR dust-bath*	0	0	
ostrich AND (peck* OR beak*)	32	4	
Papers retained from secondary searches		24	

Total number of papers retained from primary and secondary searches: 9 + 24 = 33

Emus

Primary Search: emu AND welfare = 7

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Transport or slaughter	1	Transportation stress and the incidence of exertional rhabdomyolysis in emus (<i>Dromaius novaehollandiae</i>) By: Menon, Deepa G.; Bennett, Darin C.; Schaefer, Allan L.; et al.
Other animals	1	Declawing ostrich (<i>Struthio camelus domesticus</i>) chicks to minimize skin damage during rearing By: Meyer, A; Cloete, SWP; Brown, CR; et al. SOUTH AFRICAN JOURNAL OF ANIMAL SCIENCE Volume: 32 Issue: 3 Pages: 192-200 Published: 2002
reviews	2	The development of ratite production through continued research By: Cloete, S. W. P.; Brand, T. S.; Hoffman, L.; et al. WORLD'S POULTRY SCIENCE JOURNAL Volume: 68 Issue: 2 Pages: 323-334 Published: JUN 2012
reference values for biochemistry	1	Hematological and serum biochemical profile of farm emus (<i>Dromaius novaehollandiae</i>) at the onset of their breeding season By: Menon, D. G.; Bennett, D. C.; Schaefer, A. M.; et al.
irrelevant	1	Fiscal and monetary policy interactions: a game theory approach By: Saulo, Helton; Rego, Leandro C.; Divino, Jose ANNALS OF OPERATIONS RESEARCH Volume: 206 Issue: 1 Pages: 341-366 Published: JUL 2013
Papers excluded from primary search	6	Papers retained from primary search: 7 – 6 = 1

Emu Secondary Searches

Search terms for synonyms of species or welfare	Hits	Additional Papers Included	Comments
Dromaius AND welfare	3	0	No additional papers detected
emu AND well-being	1	0	Paper on (evaluating midwifery units)
Search for sub-sets of terms relevant to welfare			
emu AND health*	35	0	Papers on health properties of ostrich meat not included. Papers on basic biochemistry, physiology and immune function not included
emu AND (stress* OR fear*)	81	0	Mostly physics (electric multiple units)
emu AND injur* OR emu AND cull OR emu AND mortali*	16	1	
emu AND (density or space)	638	1	Mostly physics
Emu AND litter OR emu AND perch* OR emu AND nest* OR emu AND enrich*	98	0	
emu AND dustbath* OR dust-bath*	0	0	
emu AND (peck* OR beak*)	6	0	
Papers retained from secondary searches		2	

Total number of papers retained from primary and secondary searches: 1 + 2 = 3

Slaughter

Web of Science was searched for: species AND subject AND interest using the terms given in the table below.

No distinction was made between the various forms of chicken.

Searches were restricted to results dated from 2000 to 2017, then further restricted to articles. Conference proceedings were excluded.

Species	
chickens	hen OR hens* OR "domestic fowl" OR (chick* NOT chickpea*) OR broiler*
ducks	duck OR ducks
geese	goose OR geese
turkeys	turkey* OR (meleagris NOT fritillaria)
guinea fowl, pheasants, partridges, pigeons and quail	quail* OR coturnix OR pigeon* NOT (pigeonpea OR "pigeon pea" OR pigeonholed) OR pheasant* OR phasianus* OR partridge* OR alectolis OR alectoris OR perdix OR guineafowl* OR "guinea fowl" OR "guinea-fowl" OR numida* OR guttera* OR agelastes* OR acryllium*
ostriches and emus	emu OR ostrich* OR ratite*
Subject	((stun* NOT stunt) OR kill* OR slaughter* OR cull* OR shackl* OR lairage OR CAS OR CAK OR "carbon dioxide" OR CO2 OR "controlled atmos" OR "low atmos" OR laps OR waterbath OR "water-bath" OR "water bath") NOT campylobacter
Interest	EEG or electroencephalo* or unconscious* or *insensib* or welfare or stress or pain or humane

For each species below, the number of papers returned from the search is given first. The number in brackets is the number of results when language is restricted to English.

Chickens

Total returns: 663 (623)

Accepted papers: 80

Only relevant and peer reviewed articles have been selected for this subject.

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	149	Captive domesticated zebra finches (<i>Taeniopygia guttata</i>) have increased plasma corticosterone concentrations in the absence of bathing water. By: Krause, E. Tobias; Ruploh, Tim APPLIED ANIMAL BEHAVIOUR SCIENCE Volume: 182 Pages: 80-85 Published: SEP 2016
Husbandry or transport	77	Effects of catching and transportation versus pre-slaughter handling at the abattoir on the prevalence of wing fractures in broilers. By: Kittelsen, K. E.; Granquist, E. G.; Vasdal, G.; et al. ANIMAL WELFARE Volume: 24 Issue: 4 Pages: 387-389 Published: SEP 2015
Other biological investigation	193	Cloning and Expression of Voltage-dependent Anion Channel 2 (VDAC2) from Electrically Stimulated Chicken. By: Hassan, Nurhidayah Ahmad; Amid, Azura; Salleh, Hamzah Mohd JOURNAL OF PURE AND APPLIED MICROBIOLOGY Volume: 7 Special Issue: SI Pages: 43-52 Published: NOV 2013
Meat quality	43	Skeletal muscle proteome and meat quality of broiler chickens subjected to gas stunning prior slaughter or slaughtered without stunning. By Salwani, M. S.; Adeyemi, K. D.; Sarah, S. A.; et al.. CYTA-JOURNAL OF FOOD Volume: 14 Issue: 3 Pages: 375-381 Published: 2016
Review paper, opinion or discussion piece	18	A review of bird welfare during controlled atmosphere and electrical water-bath stunning By: Johnson, Cia L. JAVMA-JOURNAL OF THE AMERICAN VETERINARY MEDICAL ASSOCIATION Volume: 245 Issue: 1 Pages: 60-68 Published: JUL 1 2014

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Describes policy development, not slaughter and welfare outcomes	7	Developing control points for halal slaughtering of poultry. By Shahdan, I. A.; Regenstein, J. M.; Shahabuddin, A. S. M.; et al. POULTRY SCIENCE Volume: 95 Issue: 7 Pages: 1680-1692 Published: JUL 2016
Paper does not use EEG to gauge consciousness	7	Effect of electrical water bath stunning on physical reflexes of broilers: evaluation of stunning efficacy under field conditions. By Girasole, M.; Marrone, R.; Anastasio, A.; et al. POULTRY SCIENCE Volume: 95 Issue: 5 Pages: 1205-1210 Published: MAY 2016
Other	49	Assessment of welfare of Brazilian and Belgian broiler flocks using the Welfare Quality protocol By: Tuytens, F. A. M.; Federici, J. F.; Vanderhasselt, R. F.; et al. POULTRY SCIENCE Volume: 94 Issue: 8 Pages: 1758-1766 Published: AUG 2015

Ducks

Total returns: 30 (27)

Accepted papers: 10

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	3	Environmental effects of the Deepwater Horizon oil spill: A review By: Beyer, Jonny; Trannum, Hilde C.; Bakke, Torgeir; et al. MARINE POLLUTION BULLETIN Volume: 110 Issue: 1 Pages: 28-51 Published: SEP 15 2016
Husbandry or transport	4	Mortality rates in poultry species and categories during transport for slaughter. By: Voslarova, E.; Janackova, B.; Rubesova, L.; et al. ACTA VETERINARIA BRNO Volume: 76 Supplement: 8 Pages: S101-S108 Published: NOV 2007
Other biological investigation	6	Pathogeny of Fatigued Walking Condition in Pekin Ducks By: Da Costa, M. J.; Oviedo-Rondon, E. O.; Wineland, M.; et al. AVIAN DISEASES Volume: 60 Issue: 4 Pages: 731-738 Published: DEC 2016
Meat quality	4	Effects of transport stress and rest before slaughter on blood parameters and meat quality of ducks. By: Zhu, Zhen; Chen, Yang; Huang, Zhengyang; et al. CANADIAN JOURNAL OF ANIMAL SCIENCE Volume: 94 Issue: 4 Pages: 595-600 Published: DEC 2014

Geese

Total returns: 13 (12)

Accepted papers: 1

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	2	Recovery of a northern New England salt marsh plant community from winter icing. By: Ewanchuk, PJ; Bertness, MD OECOLOGIA Volume: 136 Issue: 4 Pages: 616-626 Published: AUG 2003
Husbandry or transport	2	Duration of transport and holding in lairage at constant postprandial delay to slaughter-Effects on fatty liver and breast muscle quality in mule ducks. By: Fernandez, X.; Bouillier-Oudot, M.; Molette, C.; et al. POULTRY SCIENCE Volume: 90 Issue: 10 Pages: 2360-2369 Published: OCT 1 2011
Other biological investigation	5	Attempts on freezing the Greylag (<i>Anser anser</i> L) gander semen By: Lukaszewicz, E.; Chrzanowska, M.; Jerysz, A.; et al. ANIMAL REPRODUCTION SCIENCE Volume: 80 Issue: 1-2 Pages: 163-173 Published: JAN 2004
Meat quality	2	The effects of electrical and controlled atmosphere stunning methods on meat and liver quality of geese By: Turcsan, Z; Szigeti, J; Varga, L; et al. POULTRY SCIENCE Volume: 80 Issue: 11 Pages: 1647-1651 Published: NOV 2001

Turkeys

Total returns: 155 (141)

Accepted papers: 22. These are of variable quality.

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	46	ASSOCIATION OF SINGLE NUCLEOTIDE POLYMORPHISMS IN THE FABP4 GENE WITH CARCASS CHARACTERISTICS AND MEAT QUALITY IN HOLSTEIN BULLS By: Ardicli, Sena; Samli, Hale; Alpay, Fazli; et al. ANNALS OF ANIMAL SCIENCE Volume: 17 Issue: 1 Pages: 117-130 Published: JAN 2017
Husbandry or transport	31	Effect of litter quality on foot pad dermatitis, hock burns and breast blisters in broiler breeders during the production period By: Kaukonen, Eija; Norring, Marianna; Valros, Anna AVIAN PATHOLOGY Volume: 45 Issue: 6 Pages: 667-673 Published: 2016
Other biological investigation	19	Immunosuppressive interactions of viral diseases in poultry By: Umar, S.; Munir, M. T.; Ahsan, U.; et al. WORLDS POULTRY SCIENCE JOURNAL Volume: 73 Issue: 1 Pages: 121-135 Published: MAR 2017
Meat quality	23	Effect of Thermal Embryonic Manipulation on the Quality of Male and Female Broiler Meat Submitted to Thermal Stress Pre-Slaughter By: Fernandes, J. I. M.; Santos, T. C.; Kaneko, I. N.; et al. BRAZILIAN JOURNAL OF POULTRY SCIENCE Volume: 18 Issue: 2 Pages: 343-349 Published: APR-JUN 2016

Guinea fowl, pheasants, partridges, pigeons and quail

Total returns: 27 (26)

Accepted papers: 2

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	14	Effects of Dietary Lycopene Supplementation on Plasma Lipid Profile, Lipid Peroxidation and Antioxidant Defense System in Feedlot Bamei Lamb By: Jiang, Hongqin; Wang, Zhenzhen; Ma, Yong; et al. ASIAN-AUSTRALASIAN JOURNAL OF ANIMAL SCIENCES Volume: 28 Issue: 7 Pages: 958-965 Published: JUL 2015
Husbandry or transport	3	The effects of transportation stress on Japanese quail (Coturnix Coturnix japonica) fed corn-based diet in comparison with wheat-based diet supplemented with xylanase and phytase By: Hamzekolaie, M. H. Mehraei; Moghaddam, A. K. Zamani; Tohidifar, S. S.; et al. JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION Volume: 100 Issue: 4 Pages: 618-622 Published: AUG 2016
Other biological investigation	7	Growth, immune, antioxidant, and bone responses of heat stress-exposed broilers fed diets supplemented with tomato pomace By: Hosseini-Vashan, S. J.; Golian, A.; Yaghobfar, A. INTERNATIONAL JOURNAL OF BIOMETEOROLOGY Volume: 60 Issue: 8 Pages: 1183-1192 Published: AUG 2016

Ostriches

Total returns: 20 (19)

Accepted papers: 1

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or subject	9	Bruises in beef cattle at slaughter in Mexico: implications on quality, safety and shelf life of the meat By: Cruz-Monterrosa, Rosy G.; Resendiz-Cruz, Veronica; Rayas-Amor, Armando A.; et al. TROPICAL ANIMAL HEALTH AND PRODUCTION Volume: 49 Issue: 1 Pages: 145-152 Published: JAN 2017
Husbandry or transport	6	Effects of pre-transport nutrient supplementation and transport duration on the post-transport blood biochemistry, bodyweight and welfare of ostriches By: Bejaei, M.; Bennett, D. C.; Schaefer, A. L.; et al. ANIMAL WELFARE Volume: 23 Issue: 2 Pages: 209-217 Published: MAY 2014
Other biological investigation	1	Adaptation of ostriches to transport-induced stress: Physiometabolic response. By: Vazquez-Galindo, Giovanni; de Aluja, Aline S.; Guerrero-Legarreta, Isabel; et al. ANIMAL SCIENCE JOURNAL Volume: 84 Issue: 4 Pages: 350-358 Published: 2013
Meat quality	2	Carcass yields and meat quality characteristics of adult emus (<i>Dromaius novaehollandiae</i>) transported for 6 h before slaughter. By: Menon, Deepa G.; Bennett, Darin C.; Uttaro, Bethany; et al. MEAT SCIENCE Volume: 98 Issue: 2 Pages: 240-246 Published: OCT 2014

Emus

Total returns: 9

Accepted papers: 0

Primary Reason for Exclusion	Number Excluded	Example of Paper Excluded for Each Reason
Other species or completely different subject	2	Magnetic and magnetostrictive properties of Cu substituted Co-ferrites By: Sekhar, B. Chandra; Rao, G. S. N.; Caltun, O. F.; et al. JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS Volume: 398 Pages: 59-63 Published: JAN 15 2016
Husbandry or transport	4	Transportation stress and the incidence of exertional rhabdomyolysis in emus (<i>Dromaius novaehollandiae</i>) By: Menon, Deepa G.; Bennett, Darin C.; Schaefer, Allan L.; et al. POULTRY SCIENCE Volume: 93 Issue: 2 Pages: 273-284 Published: FEB 2014
Other biological investigation	1	Adaptation of ostriches to transport-induced stress: Physiometabolic response. By: Vazquez-Galindo, Giovanni; de Aluja, Aline S.; Guerrero-Legarreta, Isabel; et al. ANIMAL SCIENCE JOURNAL Volume: 84 Issue: 4 Pages: 350-358 Published: 2013
Meat quality	1	Carcass yields and meat quality characteristics of adult emus (<i>Dromaius novaehollandiae</i>) transported for 6 h before slaughter By: Menon, Deepa G.; Bennett, Darin C.; Uttaro, Bethany; et al. MEAT SCIENCE Volume: 98 Issue: 2 Pages: 240-246 Published: OCT 2014
Review paper	1	The development of ratite production through continued research By Cloete, S. W. P.; Brand, T. S.; Hoffman, L.; et al. WORLD'S POULTRY SCIENCE JOURNAL Volume:68 Issue:2 Pages: 323-334 Published: JUN 2012

