Animal welfare and values

Final Project Report | **APRIL 2019**

A report for Australian Eggs Limited

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Australian Eggs Limited Publication No. 1HS904a

ISBN 978-1-920835-27-9

Project Title: Animal welfare and values

Australian Eggs Limited Project Number 1HS904

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Published in April 2019

Foreword

This project was conducted to address the increasing social demands for assurance of good animal welfare and a general 'social licence to operate'. Community or public values create expectations of how animals ought to be treated. These elements are a necessary intersection with animal welfare science but have the potential to affect the interpretation of the science, where assumptions can be made as to how scientific knowledge is created and how it should be applied.

This project was funded from industry revenue which is matched by funds provided by the Australian Government.

This report is an addition to Australian Eggs Limited's range of peer reviewed research publications and an output of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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Acknowledgments

Australian Eggs Limited provided the funds which supported this project.

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1 Abbreviations

ACTH	Adrenocorticotropic hormone
AGP	Alpha-1 acid glycoprotein
APP	Acute phase protein
AWSC	Animal Welfare Science Centre
Bn	Barn
CC	Conventional cage
CGB	Corticosteroid-binding globulin
CM	Cumulative mortality
CPM	Counts per minute
CNS	Central nervous system
CRF	Corticotropin releasing factor
CVO	Chief Veterinary Officer
FC	Furnished cage
FR	Free range
h	Hour
HHP	Hen housed production
H/L	Heterophil:Lymphocyte ratio
HPA	Hypothalamic-adrenal-axis
HSA	Human serum albumin
GR	Glucocorticoid receptor
min	Minute
MR	Mineralocorticoid receptor
ng/ml	Nanogram/millilitre
PBS	Phosphate buffered saline
pg/ml	Picogram/millilitre
PVN	Paraventricular nucleus
RBC	Red blood cells
RIA	Radioimmunoassay
SEM	Standard error of the mean
TI	Tonic immobility

Executive Summary

Although the conduct of scientific research is viewed as a highly objective process, there are values-based elements in the choices made about what to study, which questions to prioritise, how to conduct the research, and how the results are interpreted and utilised in the scientific, public, regulatory and commercial arenas. The purpose of this report was to examine the values-based elements underlying the consensus in animal welfare science across key areas related to laying hen welfare, and to propose how these values-based elements can be better exposed and examined, in order to test the assumptions therein, and potentially to open the way for additional and new ways of researching key areas of hen welfare.

The Panel of authors and AWSC team thus undertook the following:

(a) A determination of the key welfare topics or pillars of hen welfare science.

(b) An examination of the existing science associated with each pillar, identifying the key papers responsible for the current scientific knowledge and consensus on an issue. If a particular topic had a large number of key papers underpinning the current consensus, then we used influential and representative papers as the key studies.

(c) An evaluation of these key welfare papers or themes to identify the values-based decisions/assumptions made by the researchers in terms of the selection of research questions and methodology; and where applicable how empirical data were interpreted in the conclusions.

(d) An examination of the values-based issues, conflicts and questions emerging from the scientific consensus, with a view to identifying researchable questions worthy of future study.

Our findings are as follows:

(i) The conduct of research to evaluate hen welfare, particularly in commercial settings, is complex because of potentially confounding differences in climatic and social environments, genetics, nutrition, and management. Furthermore, some of the confounding factors are inherent to some specific housing systems.

(ii) These challenges have led to values-based elements in designing, conducting and interpreting studies.

(iii) Funding agencies generally allocate resources to what they see as their priorities, and thus the source of funding along with other factors may influence what questions get researched.

(iv) The very act of designing a study to examine a particular situation associated with hen welfare is in itself subject to value judgements. For example, studies that examine the impact of beak trimming rely on an assumption that altering the confirmation and anatomical structure of a bird is necessary to avoid the damage of feather pecking and cannibalism.

(v) Values-based elements may influence the choice by researchers to focus on a particular measurement approach in hen welfare studies (e.g. behaviour or physiology); these choices may be made because of resource limitations in the conduct of the research, the particular expertise of the research team, the fact that it may not be feasible to measure behaviour in some contexts or physiology in others, and finally an unspoken assumption by a research team that while they are illuminating one aspect of hen welfare, other researchers will be filling in the gaps in their studies.

(vi) How data are interpreted can also have values-based elements. The use of a variety of indicators of health, physiology and behaviour to assess welfare in animal welfare research is becoming increasingly common. However, there is at present little agreement amongst researchers on integrating or weighting these indicators.

(vii) In terms of values that emerge in how the scientific consensus is viewed or utilised, key value conflicts and questions are inevitably associated with trade-offs, such as balancing some welfare attributes against others.

(viii) The key values-based elements and questions that arise from the science are identified as:

(a) Difficulties in prioritisation of values associated with motivated behaviours.

(b) Is providing hens with 'natural' lives the most important value?

(c) Which values are most important in housing system choice?

(d) Articulation of an acceptable minimal range of living states.

(e) Should interventions (e.g. beak trimming) be reduced wherever possible?

(f) Should hens be bred or reared specifically to 'avoid' some of these values-based trade-offs?

(g) Conflicts between maximising hen health versus human health.

(h) What roles should public values play in choices about egg production and hen housing systems?

(ix) Some of the trade-offs detailed above represent value conflicts where there are not likely to be straightforward scientific answers, definitive empirical evidence that will help decide which outcomes are preferred, and/or how conflicts are resolved. In many cases, developing more detailed social science research may assist in determining which community values are associated with each of these issues, and also in considering how members of the broader community and those within the egg industry might fruitfully participate in decisions about best practices in these domains.

Overall Conclusions

It is important to recognise that values-based elements, whether within the design and conduct of animal welfare science, or in how the science is viewed and utilised, can never be eliminated (Elliott 2017a). Rather, the broad goal should be to promote as much transparency as possible (Elliott 2017b), and to develop frameworks to understand and if possible reconcile trade-offs so that there are approaches or tools available to balance complex issues in animal welfare assessment. The use of a variety of indicators of health, physiology and behaviour to assess animal welfare in research studies is becoming increasingly common. However, there is at present little agreement amongst researchers on integrating these indicators, and a framework to advance this would be beneficial.

Where researchers, through necessity, focus on particular types of welfare measurements in the evaluation of animal welfare in particular contexts, there is a clear need for other studies to be undertaken on the complementary welfare measurement approaches to complete the overall assessment.

A number of social science approaches may be deployed to address the values-based trade-offs and questions that emerge from the science. These will be necessary because values are an essentially human phenomenon, and seeking to understand them in the context of animal welfare science and its application will require the human sciences as much as the animal sciences.

In summary, there are inevitable values-based judgements and considerations within the conduct and reporting of animal welfare science (some of which are highlighted in this report), and there are significant values-based questions and conflicts that emerge from animal welfare science, particularly as trade-offs between welfare indicators/pillars cannot be avoided, as identified in this report.

We propose that the key value conflicts and questions identified in this report provide the basis for researchable questions for future study, requiring the addition of social science into the stable of methodologies employed by the egg industry research program.

1 Introduction

The welfare of laying hens is of interest to society, egg consumers and retailers, animal welfare interest groups, government and policy makers, animal scientists, and the industry itself. When formulating policy, or deciding on best practices in hen welfare, the modern mantra is that animal welfare decisions need to be underpinned by good science. Because of the contentious nature of laying hen housing and management practices that developed in the latter part of the 20th century, there has been a considerable body of scientific research aimed at evaluating, comparing and improving bird welfare in relation to management practices and hen environments. Although the field is continually evolving, the current scientific consensus around key areas influencing bird welfare has been guided by a relatively small number of published papers examining each issue, often taking a singular approach of assessing welfare either through behavioural or physiological measures. In some cases, there are a small number of highly influential papers on a particular topic, whereas for other issues the consensus may be built from a larger number of findings.

Although most scientists would disagree with the thesis that the conduct of science is 'value-free' (for accessible discussions on this idea, see Elliott 2017a, b), the training received during a research-based higher degree typically emphasises straight-line logic-based thinking that does not typically prompt reflection on values or beliefs that may underlie scientists' choices at various stages in their research. The values-based elements that arise when considering the existing animal welfare science are at least four-fold.

Firstly, there are values-based elements in the very concepts and definitions associated with key ideas within any practice of science; in the case of hen welfare, ideas of the 'natural', 'normal', and so on may be thought of differently depending on point of view but these differences are often not visible when the terms are used in the scientific practices or publications resulting from research.

Secondly, there are values-based elements underlying the decisions by researchers on the specific research question that is to be tested by the study, and the particular situations chosen for comparison including the variables selected for measurement.

Thirdly, the choice of methodological approach may have a values-based component (Fraser 2003). Specifically, the values present in the scientific research are influenced by the assessment framework that the researcher has adopted. The 'biological functioning' framework is strongly evidence-based and empirical, involving well understood indicators of biological function and disfunction, but nonetheless involves values including that relevant considerations can be measured using these indicators. The 'affective states' framework necessarily involves more values-based considerations. Affective experiences, including emotions, are subjective states and cannot be measured directly in animals, although there are informative indirect physiological and behavioural indices that can be used (with caution regarding their limitations) to attempt to develop interpretations of such experiences. However, scientific methods for measurement of some positive affective states are elusive and additional methods are still being sought. Values-based considerations play out strongly in this context. Additional aspects of methods such as making data publicly available to permit replicability and publishing results in peer-reviewed outlets are critical to making assumptions about values more visible and permitting discussion and criticism by the broader scientific community as well as practitioners and even the general public.

Fourthly, where the researchers derive a conclusion about the state of bird welfare from an empirical set of data, there are inevitably values-based elements underlying this process that may influence the researchers' final conclusions. For instance Sandoe et al. (2004) examined how scientists should

handle levels of uncertainty when translating animal welfare data into animal welfare advice. They argued that it was essential for researchers to examine and state the assumptions on which the advice was based. If we consider that the researchers' own values may underpin what assumptions are made, there is a further underlying level of enquiry that is relevant. A similar set of issues arise in relation to risk/benefit judgements as different interpretations of what constitutes adequate benefit or appropriate risk are notoriously common amongst those in different research groups or even with different types of scientific training or disciplinary background.

Once results of the research performed by animal welfare scientists are published, additional values underpin the policy or other responses by governments, industry and the public and consumers. For example, if a bird is moderately stressed by a particular procedure or management environment, how do we decide whether such stress is acceptable? This type of question is particularly complex when trade-offs need to be considered, such as balancing one attribute of bird welfare against another or balancing a moderate bird stress response against better bird health or improved economics for producers. As described in a recent report by Millar (2018), this context is where the tools of science are used within a framework of values, and the final decisions about animal welfare are grounded in values-based considerations about what people believe to be more (or less) appropriate.

Although it is beyond the scope of this review, it is also important to acknowledge that the funding sources and allocations are likely to underpin values-based components and other influences. In animal welfare research, animal advocacy groups often focus on the fact that much of the research is industry-funded or co-funded with the addition of government matching funds. Such criticism is invalid where it insinuates that researchers who participate in industry-funded research invariably produce biased or invalid studies because of the funder's stated or assumed preferences. However, it is undoubtedly the case that funding agencies allocate resources to what they see as their priorities, and the priorities for an industry funding animal welfare scientific research may be different than if government alone or animal advocacy groups were providing funding, and making the specific decisions about the key research questions and methodologies. Thus, the source of funding may influence *what* questions get researched. It also is clear that it is critical to maintain transparency about funding sources and potential or perceived conflicts of interest in order to resist and mitigate sources of bias, for instance through what are now conventional declarations of conflicts of interest and similar as well as open publication of results, be they negative or positive.

The purpose of this report is to examine the values-based elements underlying the current consensus in animal welfare science across key areas for laying hen welfare, and to propose how these values-based elements can be better exposed and systematically examined, in order to test the assumptions therein, and to open the way for new approaches to researching key areas of hen welfare. The focus is on hen welfare during rearing and production. Other aspects in different stages of the value chain, such as the fate of male chicks and final hen transport and slaughter, have not been considered in this report although they raise issues relevant to animal welfare.

2 Methodology

The examination of values-based elements included the values within research on which the current consensus about animal welfare science is based, as well as the identification of values-based elements arising from applications of the science.

2.1 Identification of values-based elements within the current consensus associated with animal welfare research

The identification of values was undertaken for key welfare topics or pillars, as proposed by Australian Eggs Limited, with the addition of several topic areas identified by the Panel, as follows:

- natural behaviours, including dust-bathing, nesting, perching, and foraging
- health, including skeletal health, feather cover, disease and mortality
- stress
- housing system – including cages, alternative housing systems (e.g. furnished cages, barns), and free range housing systems
- feather pecking and cannibalism
- beak trimming
- smothering
- antibiotic use
- management practices and stockmanship.

Although the fate of male chicks is often raised as a welfare and/or ethical issue for the layer industry, it was not included in this report, which has a focus on the welfare of laying hens.

Within each welfare topic, the project team undertook a desk-based examination of the existing scientific research, identifying the key papers responsible for the current consensus on particular issues. This review was based on known impact in the area, citations (particularly in influential reports and reviews), and journals in which the research was published. If a particular topic had a large number of key papers underpinning the current consensus, then key common approaches and findings of the studies were identified, and we used influential and representative papers as the key studies. The key papers within each topic were then summarised and critically evaluated in terms of their design, robustness of conclusions, and the values-based elements that underlie the studies. The latter included where applicable: a) selection of research question; b) selection of methodology; and c) how empirical data were interpreted in the conclusions.

2.2 Identification of values-based elements emerging from application of research findings

The project team also undertook an examination of the values-based elements associated with policy or other responses by governments, industry, and the public and consumers arising from applications of animal welfare research findings. This process included an examination of the values-based assumptions of underlying trade-offs, such as balancing one attribute of bird welfare against another or balancing a moderate bird stress response against better bird health or improved economics for producers.

3 Value-based elements within the current consensus associated with animal welfare research

3.1 Common challenges in assessing welfare

It is well accepted that there is no single measure of welfare. Information using a variety of indicators of health, physiology and behaviour is required to draw overall conclusions (that is, a multi-disciplinary approach is required to assess animal welfare). Furthermore, these indicators may vary depending on the specific stressor; cluster together so there is a risk of over-estimation; vary depending on the specific stressor; and not co-vary in a consistent manner across differing housing or husbandry conditions. There is little agreement at present between researchers on the specific weightings that should be assigned to each indicator.

Evaluating housing systems particularly in commercial settings is complex because of potentially confounding differences in climatic and social environments, genetics, nutrition, and management, although some of these factors or differences in these factors are inherent to the housing system (e.g. use of litter versus soil, or variation in temperature). However, it is also difficult to replicate the scale or size of commercial systems in laboratory settings. These challenges lead to values-based elements in designing, conducting and interpreting studies.

Research question

Funding agencies generally allocate resources to what they see as their priorities, and thus the source of funding, and the values held by the funding agency, can influence what questions get researched and how research questions are framed.

Study design and selection of animal welfare measures used

There are values-based elements underpinning many aspects of the design and methodology of key animal welfare studies. For example, the design and methodology of some studies may be focused on the assessment of animal physiology in evaluating hen welfare responses to different management environments or procedures. More particularly, some key papers use bird mortality as the main measure of welfare, such as in Weeks et al. (2016), in which mortality was higher in free range flocks than for conventional cage housing, and reduced within free range flocks where birds were beak trimmed. Similarly, Fossum et al. (2009) measured mortality across hen housing systems and recorded higher mortality where hens had access to litter.

Although the selection of a particular set of welfare measures within a research study has a values-based component, it should not be assumed that this is because the researchers inherently value one measurement approach (or attribute of bird welfare) over another. It is the Panel's assessment that often these choices may be made because of resource limitations in the conduct of the research, the particular expertise or training of the research team, the fact that it may not be feasible to measure behaviour in some contexts or physiology in others, and finally unspoken assumptions by researchers that while they are illuminating one aspect of hen welfare, other researchers will be filling in the remaining gaps with their studies. Furthermore, the specific question that the research is addressing may be broader than welfare *per se*; it may also be addressing productivity, as well as economic and thus industry-sustainability implications of the problem (e.g. mortality in free range laying hens).

Nonetheless, studies that become seminal in the welfare canon often have a particular measurement focus, which can in turn influence how these studies are interpreted in terms of hen welfare.

Furthermore, it ought to be recognised that the very act of designing a study to examine a particular aspect of hen welfare is in itself subject to value judgements. For example, studies that examine the impact of beak trimming, or compare methodologies to achieve a more welfare-friendly process for beak trimming, depend on the surface on an assumption that altering the confirmation and anatomical structure of a bird is necessary to avoid the damage of feather pecking and cannibalism.

Interpretation of results

How data are interpreted can also have values-based elements. In hen housing research, two of the studies confound housing system with location, raising the possibility of bias in the interpretation of the data due to differences in environment, nutrition, and management (Sherwin et al. 2010, Koelkebeck et al. 1987) as well as genetics (Sherwin et al. 2010). The use of a variety of indicators of health, physiology and behaviour to assess welfare in animal welfare research is becoming increasingly common. However, there is at present little agreement amongst researchers on how to integrate or weight these indicators.

4 Values emerging from applications of research findings

It is clear that many of the pillars identified in this document are interrelated and have interdependencies; indeed, in some cases focus on one pillar alone may produce considerable adverse effects in terms of some of the other pillars. For instance, levels of antibiotic use are likely to be influenced by levels of bacterial disease; beak trimming is related to feather pecking and cannibalism; housing systems have a major impact on health, behavioural expression, and smothering; and management and stockmanship is relevant to all housing systems. The body of scientific findings summarised in this report indicates that due to these interdependencies and relationships, no one production or management system for hens can provide optimum welfare outcomes across all of these measures (or pillars). Balancing some welfare attributes against others seems necessary, indeed inevitable, and hence we consider the potential trade-offs inherent in the complexities associated with these pillars.

In considering that balance, a considerable range of questions, and indeed conflicts, emerge, the answers to which mostly involve the application of values-based considerations as they relate to the inevitable trade-offs inherent in achieving 'balance,' or at least trade-offs that warrant more conscious exploration and decision-making by those in the industry, scientists involved in research and development, and members of the broader community. These trade-offs represent value conflicts where there are not likely to be straightforward scientific answers, or definitive empirical evidence that will help us to decide which outcomes are preferred. Notwithstanding the potentially large number of these values questions presented by the science, there is considerable overlap and thus opportunity for these to be consolidated into a lesser number of key 'trade-off categories', which could represent researchable questions that could form the basis for future study.

In no particular order of significance or importance, key value questions and conflicts associated with the trade-offs inherent in the pillars above that have been identified include:

(i) **Difficulties in prioritisation of values associated with motivated behaviours:** For instance, is it more important that hens have opportunities to express a wide range of motivated behaviours or that they are protected from bacterial or viral infectious diseases caused by contact with faeces and contaminated soil and bedding; and/or that they are managed in a way that allows closer monitoring and prompt intervention should welfare problems arise? To what extent should welfare benefits such as freedom from predation, lower exposure to disease infections and parasites, lower levels of smothering due to 'pile ups', and lower death rates of hens be traded off (i.e. deemphasised) in order to provide greater opportunities for hens to express motivated behaviours?

(ii) **Is providing hens with more 'natural' lives the most important value?** Should we prioritise more 'natural' settings (such as those provided by barn and free range production systems) over other 'less natural' settings (such as cages) even if at the expense of certain welfare benefits (e.g. where death rates are documented to be higher)? Is the answer likely to remain the same even if more 'natural' settings inevitably increase situations and behaviours associated with fear, pain, sickness and injury?

(iii) **Which values are most important in housing system choice?** Should protection from negative states be the most important consideration, or does this need to be balanced with promotion of some positive states? Expressed another way, is it sufficient to avoid suffering, or should there be opportunities for positive affective states?

(iv) **Articulation of an acceptable minimal range of living states:** Is it sufficient that birds are protected from pain, disease, injurious behaviours from others such as feather pecking and cannibalism, predation, and smothering (i.e. harms), or should their living conditions promote a range of positive states and experiences (such as contentment, freedom to roam, and so on)? Is it acceptable to 'trade off' prevention of harm with promotion of positive states, and if so, how could an appropriate and justifiable balance be reached and by whom?

(v) **Should interventions be reduced wherever possible?** So, for instance, is it more important that hens are not subjected to physical interventions such as beak trimming, or that they are free from injury and stress from pecking behaviours by engaging in beak trimming? If one housing system enabled an intervention such as beak trimming to be avoided or reduced, but restricted some types of behavioural expressions, how could valid judgements about this trade-off be made?

(vi) **Should hens be bred or reared specifically to 'avoid' some of these values-based trade-offs?** So, if it were feasible to breed strains of hens that have fewer motivated behaviours (and thus would not be as frustrated by lack of opportunities for such behavioural expressions as compared to those with the genotypes typically utilised today), should such breeding programs be promoted to avoid the need to provide for such behaviours? Similarly, if it were feasible to rear pullets in such a way as to minimise their desire (or lower their motivation) to express certain behaviours, is this an acceptable means to avoid the need to provide for such behaviours later in hen management systems?

(vii) **Conflicts between maximising hen health versus human health:** Is it more important that hens are protected from the harmful effects of bacterial diseases through higher rates of antibiotic use (i.e. making certain hens are healthy) or that people are protected from antibiotic-resistant infections by lower rates of antibiotics use including in agriculture settings? Can human health be traded off against hen health and welfare?

(viii) **What roles should public values play in choices about production and housing systems?** So, for instance, is it sufficient for people to have access (at the point of sale) to eggs produced using a range of production practices (and thus allowing them to make choices based on other characteristics such as price point, taste, convenience, and so on), or should all eggs be produced according to the dominant or average preferences expressed in the broader community?

(ix) **Is consumer choice sufficient?** Given that the science indicates that no one production system provides optimum outcomes in terms of all of the key welfare 'pillars', that the determination of an 'acceptable balance' lies in values-based considerations, and that no system allows birds to suffer as defined in animal welfare legislation, is it sufficient that people are provided with a choice of eggs produced using a range of production systems alongside other considerations such as price, taste, convenience and so on, to allow personal values to be accommodated when purchasing eggs?

5 Research methodologies to address values and conflicts

Many of the trade-offs surveyed above represent value conflicts where there are not likely to be straightforward biological answers, or definitive scientific evidence that will help us to decide which outcomes are preferred. In many cases, developing more detailed social science research may assist in determining which community values are associated with each of these issues, and also to allow consideration of how members of the broader community and those within the egg industry might fruitfully engage about best practices in these domains. The following summary provides several social science approaches that could prove useful in order to investigate the key values-related questions outlined above in relation to the Australian production context.

Firstly, many of the issues raised involve values in conflict, or trade-offs between various potential benefits and potential harms. Hence the use of approaches such as participatory or social multi-criteria evaluation methodologies, which allow structured and transparent ranking of competing values, could be particularly useful when combined with facilitated deliberative approaches that permit discussion of trade-offs among stakeholders before formulation of weighted and prioritised values. For instance, trade-offs between fostering motivated behaviours and considerations relating to hen health, death, and so on could serve as foci for such studies, as could considerations about balancing prevention of harm in relation to promotion of positive states.

Secondly, more conceptual excavations using qualitative methodologies such as focus groups, interviews, or similar with a diverse range of community members could be profitable with reference to some of the key concepts underlying the values conflicts associated with egg production, including what counts as the 'natural' and why, or which values are typically associated with attitudes toward particular production systems (e.g. free range versus cage).

An additional cluster of issues relates to policy-associated issues, such as appropriate rates of antibiotic use in hens and in humans, and considerations about minimal standards for egg production and whether market forces should be the dominant decider: here established methodologies include use of deliberative and participatory approaches including citizen juries.

Finally, facilitated deliberative discussions with community, industry, and other stakeholders could allow synthesis of a number of the issues discussed above, for instance by including testimony from a range of perspectives including those utilising various production methods and holding diverse views on hen welfare, and producing a series of policy recommendations in response to key questions associated with trade-offs.

6 Appendices

6.1 Appendix 1 – Natural behaviour

Dawkins MS (2008) – The science of animal suffering.
Ethology 114, 937-945

Aim

This review paper considers the general topic of whether suffering in non-human animals can be studied scientifically, and while not the focus of the review, proposes how suffering can be assessed when an animal is deprived of the opportunity to perform natural behaviour.

Methods

This paper reviews and provides a perspective on:

(i) studying suffering in non-human animals scientifically;

(ii) the proposition that positive and negative emotional states can be defined by asking animals what they find positively and negatively reinforcing;

(iii) the importance of health and what animals want; and

(iv) the importance of studying farm animals *in situ*.

Main findings

The author proposes that:

(i) By asking animals what they find positively and negatively reinforcing (what they want and do not want), we can define positive and negative emotional states.

  (a) For example, relieving pain, finding shelter and finding water to drink are all what psychologists call positive 'reinforcers', that is they are sufficiently positive or rewarding to cause people and animals to repeat the action that resulted in them. Conversely, having pain inflicted or being subjected to a frightening stimulus are negative reinforcers or punishers and cause people and animals to avoid doing the action that led to them in the future. By defining suffering as emotional states characterised by being caused by negative reinforcers gives us an objective, measurable and behavioural way of understanding what matters to animals.

(ii) Using positive and negative reinforcement as the core definition of suffering in this way allows us to view other 'measures' of suffering (e.g. specific behavioural and physiological responses such as vocalisations and glucocorticoids *in situ*) more coherently by asking how well they correlate with the core.

(iii) An operational definition of negative emotion, however, does not completely define 'welfare' because what animals choose or will work for may not be good for their health in the long run.

  (a) In addition to asking animals want they want and do not want, any assessment of animal welfare must similarly take into account what improves physical health, both what reduces disease, deformity and injury as well as what promotes positive health,

good growth and longevity. Good health is so fundamental to good welfare that we cannot define welfare or suffering without it.

(iv) Asking whether animals suffer if deprived of the opportunity to perform natural behaviour requires an understanding of topics such as how behaviour is triggered and controlled, the effects of early experience and genetics, the behavioural and hormonal effects of deprivation, a knowledge of how that species behaves in the wild, its brain activity and probably a great deal more as well.

(v) Therefore, the use of positive and negative reinforcers (what animals want and what animals do not want) together with basic measures of animal health provides a two-question framework for animal welfare science.

(vi) Furthermore, it is important that this type of research is conducted *in situ* so that it is directly applicable to the real world of farming.

Authors' conclusions

(i) The use of positive and negative reinforcers (what animals want and what animals do not want) together with basic measures of animal health provides a two-question framework for animal welfare science. The two questions are: Q1. Are the animals healthy? Q2. Do the animals have what they want?

(ii) These two questions have the advantage that they cover what most people mean by good welfare and therefore provide a definition of good welfare (healthy animals that have what they want) that can be understood and subscribed to by farmers, scientists and the public at large.

(iii) They allow us to make sense of other controversial measures of welfare such as 'naturalness', 'stress' hormones, and above all they tell us what we have to find out in practice so as to assess and improve animal welfare in the real world.

Values-related components

(i) The paper attempts to establish how positive and negative reinforcement can be used as proxy measures for what animals want; despite the evidence presented, the equation of these might be taken as suggesting that meeting basic needs is sufficient, which could be viewed as a very minimalistic understanding of good welfare.

(ii) The goal of establishing a 'scientific' (or perhaps more objective) measure of welfare relies heavily on the biological functioning model; nevertheless, the assessment framework adopted necessarily contains values-based elements associated with the framing of research questions and the variables selected for measurement.

(iii) There are clearly values-based elements associated with certain key concepts and definitions in this study, notably the use of the 'natural' with reference to behaviours.

(iv) There is a value judgement inherent in the assumption that animals that do not get what they want (but remain healthy) necessarily experience a negative welfare state.

Mason GJ and Burn CC (2011) – Behavioural restriction.
Animal Welfare, edited by M. C. Appleby, J. A. Mench, I. A. S. Olsson and B. O. Hughes
CAB International, Oxon UK, pp. 98-113

Aim

This review chapter covers what biologists have since discovered about the psychological effects of behavioural restriction, and how it can impair welfare even when physical health is fine.

Methods

This chapter covers several psychological aspects of impoverished environments that are relevant, including those where sensory environments may be inappropriate (e.g. over- or under-stimulating), and where captive animals' lack of control over their lives may be inherently stressful. The emphasis, however, is on the motivational effects of such environments – on consequences such as specific frustrations and more generalised boredom. The chapter:

(i) briefly reviews the techniques used to identify behaviour patterns that animals need to perform if welfare is not to be compromised;

(ii) provides examples, focusing on the best understood and emphasising the specific natural behaviour patterns; and

(iii) finally, discusses whether impoverished environments also cause boredom.

Main findings

The authors propose that:

(i) Encouraging captive animals to perform all the behavioural patterns evident in the wild is neither sensible nor humane because many of these behavioural responses may be responses to adversity.

(ii) Furthermore, many of the 'wild' behaviours are perfectly natural, but their absence in captivity should not necessarily raise welfare concerns because they are elicited by external stimuli or physiological states that have already been fulfilled in animals whose safety, physical, social, health and nutritional needs are met.

(iii) Welfare researchers, therefore, do not catalogue all natural behaviours to try to ensure that each is performed in captivity. Instead, they try to identify the subset whose performance is likely to benefit welfare, because driven by high motivations that still occur in captivity, behavioural deprivation implies not only that an animal is prevented from performing behaviour, but that adverse effects arise as a result. Critical here is the idea that frustrating motivated behaviours compromises welfare.

    (a) One means by which this happens is through frustrating specific motivations pertaining to particular behavioural systems. This can occur when constrained behaviours are 'behavioural needs': activities that animals have instincts to perform even in environments where they are not biologically necessary for fitness (e.g. non-nutritive sucking by calves).

    (b) It can also occur when deficits or external cues in the environment elicit strong motivations to behave a certain way (e.g. the lack of burrow-like structures triggering digging attempts in gerbils).

(c) Furthermore, given that humans suffer boredom in monotonous conditions that resemble those of the environments of many captive animals, and that many animals actively seek stimulation, it seems likely that, at least for some individuals in some species, behavioural restriction also harms welfare by thwarting general motivations to seek variety and/or to avoid monotony.

(iv) Concerns that inabilities to perform natural behaviour compromise welfare are to a large extent concerns about unsatisfied motivations: that animals are frustrated – with the negative emotions that this involves – if captive conditions either lack the right stimuli or substrates, or are too cramped and physically constraining, to enable consummatory behaviours. There is a spectrum of highly-motivated behaviours:

(a) At one end of a spectrum of highly motivated behaviours are the so-called 'behavioural needs': activities that animals have instinctive, intrinsic propensities to perform, whatever the environment is like, even when the physiological needs that the behaviour serves are fulfilled, and even when these behaviours are not necessary for fitness.

- E.g. being motivated to perform natural foraging even when nutritionally sated.

(b) At the other end of the spectrum of highly-motivated behaviours are activities induced by the animal's external circumstances: thus, deficits or external cues in the environment elicit the motivations.

- E.g. being highly motivated to forage because nutritionally deprived.

(v) Research methods to identify motivational frustration include:

(a) behavioural effects – redirected behaviours (e.g. aggression and feather-pecking), displacement activities (e.g. polydipsia) and stereotypies (e.g. pacing and oral-nasal activities);

(b) physiological effects – especially sympathetic responses such as elevated blood pressure and glucocorticoids, immunosuppression;

(c) measuring preference – assessing whether animals will learn arbitrary operant responses such as lever pressing to perform natural behaviours; and/or making it difficult to do so (e.g. increasing the number of lever presses required to gain access, or imposing natural barriers such as gaps to squeeze through, or heavily weighted doors to push, in order to assess motivations for various goals ('behavioural demand' studies); and

(d) fitness effects – reduced growth and reproductive efficiency, impaired wound healing, and high mortality.

Authors' conclusions

(i) Denying specific strongly motivated behaviours is one potential cause of welfare problems in barren environments. Strong specific motivations may be induced by the presence of certain external stimuli, the lack of appropriate resources in the environment and/or intrinsic requirements to perform certain natural activities (so-called 'behavioural needs').

(ii) Research has also identified a diverse array of natural behaviours that animals prefer to perform when they can, but whose absence has an uncertain or unknown effect on the welfare of animals who have never experienced these behaviours (mouse killing by rats and swimming by mink being two examples).

(iii) In addition to specific behavioural frustrations, more general, non-specific boredom is also a real possibility, especially for neophilic species and individuals. For example, sometimes

rather dissimilar enrichments, which appear as outlets for quite different motivations, can have surprisingly similar effects on the abnormal behaviour and stress physiology of animals.

Values-related components

(i) A key set of assumptions underlie the research in this paper relating to the concepts and definitions utilised, notably the use of the 'natural' with reference to behaviours and in particular what could be argued to be its redefinition to exclude behaviours in response to adversity as well as its focus on 'motivated' behaviours.

(ii) This paper focuses on conditions under captivity for production animals, and hence may already be assuming a certain baseline of conditions within which details might be tweaked or modified, rather than considering optimal conditions for animal welfare more broadly.

Cooper JJ, Appleby MC (1996) – Demand for nest boxes in laying hens.
Behavioural processes 36, 171-182

Aim

This study builds on earlier studies by attempting to quantify the value of a discrete nest site relative to a meaningful measure of value (access to food).

Methods

Twelve Isa Brown hens (*Gallus gallus domesticus*) were trained to open a locked door for access to a pen containing an enclosed nest box ('nest test') and to return to a home pen containing food, water, litter and a perch ('home test'). The door was connected to a computer-controlled load cell, which recorded work exerted on the door, and unlocked the door when the hen had exceeded a predetermined workload. Following training, the workload was set at 10 Ns, and hens received one nest test per day at 80, 60, 40 or 20 min prior to oviposition, and then one home test per day after 1, 2, 3 or 4 h confinement in the nest pen.

Main findings

(i) As oviposition approached, hens showed a higher work-rate for access to the nest pen, showed a shorter latency to use the nest box and spent a greater proportion of their visit time in the nest box. Hens also worked harder for the home pen, showed a lower latency to feed and spent more time feeding after their return as period of confinement increased.

(ii) The hens' work-rate for the nest pen at 40 min prior to oviposition was comparable with their work-rate for the home pen after 4 h confinement, while their work-rate was at its highest in nest tests at 20 min prior to oviposition (Figure 1).

(iii) The technique appears to be a valid means of assessing the importance of environmental resources, the values of which vary with time. The results suggest that hens place a higher value on gaining access to a discrete nest-site prior to oviposition than they do on gaining access to food following 4 h food deprivation.

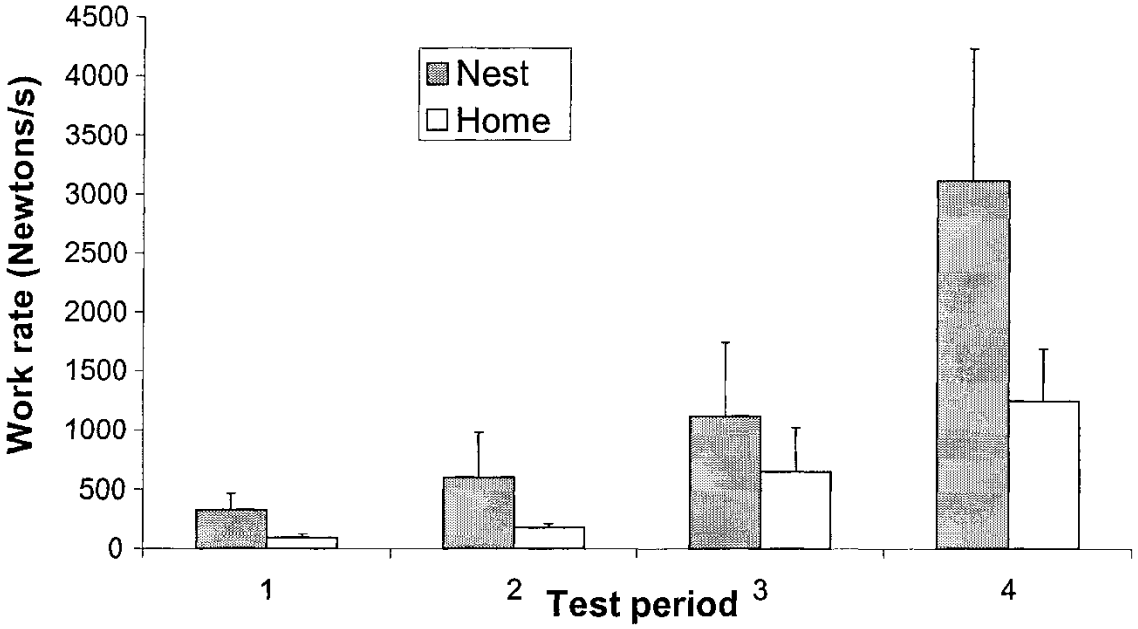

Figure 1 The work-rate exerted on the push-door to gain entry to the nest pen at 80(1), 60(2), 40(3) and 20(4) min prior to oviposition, and the work-rate to gain entry to the home pen after 1, 2, 3 and 4 hr confinement in the nest pen

Authors' conclusions

(i) This study shows that the push-door can be used as a means of assessing hens' motivational state and for assessing the importance of environmental resources over specific time frames. Consequently, investigating the hens' work-rate may be an alternative means of investigating the utility of resources to conventional measures of utility based on demand function (Mason 1998, Dawkins 1990, Mason et al. 2001), particularly where the resource's incentive value can vary with time.

(ii) In this study, the hens worked significantly harder to gain access to a pen containing a nest box prior to oviposition than they worked to gain access to a pen containing food after several hours' food deprivation. Longer periods of food deprivation may be required to equate the work-rate for a nest prior to oviposition with an equivalent level of feeding motivation, but this could involve unacceptable levels of hunger.

(iii) Nevertheless, the findings of this study reinforce the conclusion that laying hens require a suitable nest-site (Hughes et al. 1989, Baxter 1994, Sherwin & Nicol 1994, FAWC 1997), and support the movement in European legislation towards the provision of discrete nest-boxes to caged laying hens (CEC 1999).

Values-related components

(i) This study relies on an assumption that food can be used as a proxy for motivation of behaviours, similar to many of the others on this topic.

(ii) The tendency to equate 'wants' with 'needs' remains a values-based component of the paper's conclusions. To conclude that hens 'require' access to a nest box for their welfare from the studied observation that hens find access to a nest box more desirable close to the point of lay than access to food, is values-laden in the absence of evidence of associated negative impacts on biological function.

Engel JM, Widowski TM, Tilbrook AJ, Butler KL, Hemsworth PH (2018) – The effects of floor space and nest box access on the physiology and behaviour of caged laying hens.
Poultry Science

Aim

This experiment examined the effects of floor space during rearing (315 or 945 cm^2/bird) and adulthood (542 or 1648 cm^2/bird), and access to a nest box, on the welfare of caged laying hens.

Methods

Sixty-four female Hy-Line Brown pullets in each of 4-time replicates (256 pullets in total) were used in this experiment. At 29 weeks of age, focus hens from the four treatments were trained in a Y-maze apparatus specifically designed for this experiment to offer either a nest box or food (when testing effects of the Nest Box treatments) or increased space when testing the effects of the Floor Space treatments. Sixteen hens (two from each cage) were selected (Nest Box treatment hens) to be tested for nest box preference over food. These hens were selected based on the regularity of their laying pattern, and therefore, the ease with which their time of oviposition could be predicted. Each of the nest box-tested hens was then randomly paired with a hen (Space treatment hens) to be tested for space preference over food. As hens were being tested for increased space preference, the Y-maze apparatus was specifically designed for this experiment to offer as little extra space as possible. The treatments in the experiment were a 2 × 2 × 2 factorial, consisting of the following three main effects:

(i) Rearing space allowance – 2 levels in groups of 8 pullets per cage from 7 weeks of age, 315 and 945 cm^2/bird.

(ii) Adult space allowance – 2 levels in groups of 6 hens per cage from 16 weeks of age, 542 and 1648 cm^2/bird.

(iii) Nest box access – 2 levels, presence or absence of a nest box during adulthood. In the latter, the nest box was present, but its access was blocked.

Measurements of the normality of biological functioning included plasma, egg albumen and yolk and faecal corticosterone concentrations, plasma corticosterone response to adrenocorticotropic hormone (ACTH) challenge, and heterophil to lymphocyte ratios, behavioural time budgets, extra-cuticular shell calcium, mortality and efficiency of productivity.

Furthermore, measurement of hen preferences, using choice behaviour in Y-maze tests, were also used to assess hen welfare. The framework of affective state to assess animal welfare is based on the concept that the welfare of an animal derives from its capacity for affective experiences and thus a common approach is preference research on the assumption that animals make choices that are in their best interest, that is, avoid aversive stimuli and choose positive stimuli (Duncan & Fraser 1997, Fraser 2003). The affective state was studied by measuring the preference of hens to access extra space and a nest box in a discrete choice test. Each measurement was analysed using a multi-strata factorial analysis of variance, with the unit of analysis being a cage of six birds.

Main findings

(i) There were no effects of treatment on physiological measurements (plasma, egg albumen and yolk and faecal corticosterone concentrations, and heterophil to lymphocyte ratios), extra-cuticular shell calcium, body weights, egg production or mortality.

(ii) While there were no effects of rearing cage on feather condition score, there were effects of both adult cage space allowance and access to a nest box on feather condition score, especially later in the study: feather condition score was worse in small cages at 34 weeks of age, and in cages with access to a nest box at 34 weeks of age. However, feather condition scores in all treatments were on average in the good to very good category.

(iii) Hens given less space during adulthood spent less time mobile, inedible pecking, drinking, and preening, and spent more time resting, feed pecking and sitting.

(iv) Hens housed with access to a nest box spent more time resting and less time sham dust bathing than hens without access to a nest box.

(v) There were no effects of space allowance on choice behaviour for space or a nest box over food, however, hens housed with access to a nest box from 16 to 29 weeks of age chose the nest box over food more than hens without access to a nest box from 16 to 29 weeks of age (nest box chosen in 22% and 1% of tests, respectively).

Authors' conclusions

(i) These results provide no convincing evidence that either reducing space allowance in adulthood from 1,648 to 542 cm^2/bird or eliminating access to a nest box results in disruption of biological function.

(ii) Furthermore, less space and no access to a nest box did not increase the choice for more space or a nest box, respectively, over food in the preference tests. Food is generally considered as the 'gold standard' in preference testing and the authors concluded that hens housed with a nest box were at least moderately motivated to choose a nest box over food near the time of oviposition.

(iii) Thus, housing hens with reduced floor space reduced behavioural freedom and denying access to a nest box eliminated the opportunity for the motivated behaviour of laying their eggs in a discrete enclosed nest box, both of which presumably provide hens with the opportunity for positive affective experiences.

(iv) Attitudes toward animal welfare have moved beyond whether the animal is suffering, and there is an emerging shift in community values toward not merely minimising suffering, but also enhancing positive affective experiences in animals. These developments, in turn, lead to questions such as the need to provide commercial laying hens with both increased space to allow more behavioural freedom and nest boxes for the opportunity to perform the motivated behaviour of laying their eggs in a discrete enclosed nest box, both of which presumably provide hens with positive affective experiences.

Values-related components

(i) This study assumes a framework associated with affective states (rather than more physiological or external metrics) to assess welfare, yet many of the metrics utilised that are biological are geared to optimisation of production (e.g. measurements of egg components and yield).

(ii) An additional underlying assumption associated with this type of preference research is that animals make choices that are in their best interests, thus assuming a very narrow band of possible choices.

(iii) The paper acknowledges that a movement of welfare assessment beyond 'avoidance of harmful states' towards enhancing positive affective experiences reflects an emerging shift in (community) values. To that end, it adds weight to the Panel's conclusion that there would

be benefit from the inclusion of avenues of social science research into the egg industry's animal welfare science program.

Summary of key literature on natural behaviour

A common view among NGOs and the public, and to a lesser extent within science, is that provision of 'natural' aspects in the animal's environment and the ability for the animal to perform its full 'behavioural repertoire' equates to safeguarding its welfare. However, as Dawkins (2008) and Mason and Burn (2011) recognise, encouraging captive animals to perform all the behavioural patterns evident in the wild does not necessarily safeguard animal welfare because many of these behavioural responses in the wild may be responses to adversity. Furthermore, as Mason and Burn (2011) remark, while many of the 'wild' behaviours are perfectly natural, their absence in captivity should not necessarily raise welfare concerns because they are usually elicited by external stimuli or physiological states that have already been fulfilled in animals whose safety, physical, social, health and nutritional needs are met.

Comments on the key papers

(i) Dawkins (2008) in her review of science of suffering, emphasises that to understand whether an animal suffers if deprived of the opportunity to perform natural behaviours requires an understanding of topics such as how behaviour is triggered and controlled, the effects of early experience and genetics, the behavioural, physiological and fitness effects of deprivation, and a knowledge of how that species behaves in the wild.

(ii) Dawkins (2008) confirms the approach taken by many researchers in studying animal motivations and welfare (see Mason & Burn 2011), that the use of positive and negative reinforcers (what animals want and what animals do not want) provides part of a framework for animal welfare science. Furthermore, understanding what animals find positively and negatively reinforcing (what animals want and do not want) may capture what most people mean by 'improving welfare' and so helps to mitigate a potentially dangerous split between scientific 'definitions' and popular or lay 'notions' of animal welfare.

(iii) Furthermore, Dawkins (2008) emphasises that the other important component in the framework for animal welfare science is whether the animals are healthy.

(iv) In a similar approach, Mason and Burn (2011) recognise that captivity often restricts the abilities of animals to perform natural behaviours and thus may frustrate specific motivations and in turn compromise welfare. Mason and Burn (2011) considered the spectrum of highly motivated behaviours from, at one end, the activities that animals have instinctive, intrinsic propensities to perform whatever the environment is like, even when the physiological needs that the behaviour serves are fulfilled, and even when these behaviours are not necessary for fitness ('behavioural needs'), through to the activities induced by the animal's external circumstances: thus, deficits or external cues in the environment elicit the motivations.

(v) In addition to assessing animal preferences (what animals want and do not want) and health, Mason and Burn (2011) recommend that research methods to identify motivational frustration should also include studying *in situ* the effects of the environment on animal behaviour, physiology and fitness.

(vi) The research by Cooper and Appleby (1996) and Engel et al. (2018) examined a high motivated behaviour, oviposition in a discrete enclosed nest box. Most hens prefer to lay their eggs in a discrete enclosed nest box, and evidence in the literature on preference and

motivation tests show that most hens prefer and are highly motivated to access an enclosed nest box around oviposition. Behavioural demand studies in which the motivation to perform a type of behaviour is measured have shown that hens near the start of the sitting phase preceding oviposition are willing to squeeze through narrow doorways (Cooper & Appleby 1996, 1997), push open weighted doors (Follensbee et al. 1992), and pass through cages occupied by unfamiliar or dominant hens (Freire et al. 1997) in order to gain access to a nest box.

(vii) The research by Cooper and Appleby (1996) reviewed here on nesting behaviour confirms other evidence in the literature that hens are highly motivated to access an enclosed nest box around oviposition.

(viii) Since food is generally considered as the 'gold standard' in preference testing (Matthews & Ladewig 1994), Engel et al. (2018) concluded that hens that had access to a nest box in their cages were at least moderately motivated to choose a nest box over food near the time of oviposition (nest box chosen in 22% of choice tests). Hens housed without nest boxes chose a nest box infrequently over food (1% of choice tests).

(ix) Motivation for nesting has been studied extensively, and a number of studies using preference and behavioural demand tests consistently show that most hens prefer and are highly motivated to access an enclosed nest site. While individual and strain differences in nesting motivation and nest box use are not well understood, Engel et al. (2018) provide no evidence that naive hens experience chronic stress, with adverse consequences on body weight and egg production, or are highly motivated to access a nest box when housed without a nest box. However, denying access to a nest box eliminated the opportunity for the motivated behaviour of laying their eggs in a discrete enclosed nest box, which presumably provide hens with the opportunity for positive affective experiences.

(x) Therefore, in terms of understanding the welfare implications of depriving animals of the opportunity to perform natural behaviours, this review of four key papers indicates that research methods should include measuring animal preferences for performing the behaviour as well as the behavioural, physiological and fitness (including health) effects *in situ* of restricting the behaviour. Without evidence of measurable effects on biological function associated with provision for, or denial of, highly motivated behaviours, conclusions about the desirability of allowing expression of these behaviours are necessarily values-laden.

6.2 Appendix 2 – Health

Fleming RH, McCormack HA, McTeir L, and Whitehead CC (2004) – Incidence, pathology and prevention of keel bone deformities in the laying hen.
British Poultry Science 45: 320-330

Aim

The aims in this paper were to determine the prevalence of keel bone deformities and relationships with other skeletal characteristics in hens of varying genetic strains kept under both free range and conventional cage systems.

Methods

Using four commercial farms across both cage and free range housing systems, a total of 1,585 adult birds were euthanased at ages ranging from 15 to 70 weeks for analysis of the keel bone, tibia and humerus. A further 632 to 664 birds were sampled from each of two divergent genetic lines, selected on the basis of bone strength index. Bones were dissected out and analysed for physical deformity (keel bones only) as well as mechanical strength, radiographic density, histopathological changes, collagen biochemistry, and ash and mineral content.

Main findings

(i) The prevalence of keel deformity on farms in end of lay hens (70 weeks) ranged from 2.6 to 16.7%, compared with 0.8% in 15-week-old birds.

(ii) Within the same farm, there was no difference in the prevalence of keel bone deformities in caged compared with free range hens.

(iii) Histopathology of keel bones showed the presence of fracture callus material and new bone. This indicated that deformities were a result of trauma.

(iv) There were no differences in collagen biochemistry or ash content in the keel bone, tibia and humerus between hens with normal and deformed keels.

(v) Bone strength and radiographic density were higher in the positively selected bird strain compared with controls.

Authors' conclusions

Lack of bone mass is the underlying cause of keel fracture and deformity in laying hens; genetic selection can improve keel quality and prevent deformity.

Values-related components

(i) This research uses skeletal deformities and other skeletal characteristics as a key measure of health, and hence may not align with more popular or lay understandings of the concept, nor may it take account of the suffering related to certain types of deformities or characteristics.

(ii) This paper's conclusion (that genetic selection can improve skeletal health) potentially gives rise to a highly values-based or ethical consideration about the acceptability of 'breeding out' a problem caused by current intensive hen housing systems.

Fleming, RH, McCormack, HA, McTeir, L, and Whitehead, CC (2004) – Relationships between genetic, environmental and nutritional factors influencing osteoporosis in laying hens.
British Poultry Science 47: 742-755

Aim

The aim was to determine the relative contributions to bone strength of genetics and nutrition (source of calcium), in caged and aviary-housed hens from two divergent genetic strains selected on bone strength.

Methods

Approximately 100 birds from each genetic strain were housed in cages, and a further 100 birds from each strain were aviary housed. Birds were fed a standard diet incorporating either limestone powder or granules. Birds were euthanased at either 15, 25 or 56 weeks and the tibiotarsus, humerus and keel bones dissected out for analysis. Bone testing included biomechanical strength, radiographic density and histopathology.

Main findings

(i) Hens from the aviary environment had improved bone characteristics compared with caged birds.

(ii) Birds from the improved bone strength selection line showed healthier bone characteristics beginning at 25 weeks and enhanced at 56 weeks of age.

(iii) Feeding limestone granules resulted in some bone improvements at 56 weeks compared with feeding limestone powder.

Authors' conclusions

Genetic selection is effective in improving bone strength. Allowing hens freedom to exercise can also improve bone strength but may increase the risk of keel damage if they do not have genetically-improved bone status. Feeding a particulate form of limestone to hens can also increase bone strength. Genetics, environment and nutrition all have independent and additive effects on bone status in laying hens, but the relative effectiveness of these factors is genetics > environment > nutrition.

Values-related components

(i) This study does not appear to examine animal suffering related to bone pathologies, which may have significant effects on their welfare.

(ii) The paper identifies a conflicting outcome in the sense that there is evidence that providing for more freedom for birds to exercise increases bone strength but may increase risk of keel damage. Any decision about the inherent 'trade-off' is clearly a values-based decision.

(iii) Like the previous paper on bone health, the conclusion (that genetic selection can improve bone strength) potentially gives rise to a values-based or ethical consideration about the acceptability of 'breeding out' a problem caused by current intensive hen housing systems.

Fossum, O, Jansson, DS, Etterlin, PE and Vagsholm, I (2009) – Causes of mortality in laying hens in different housing systems in 2001 to 2004.
Acta Veterinaria Scandinavica 51: 3 doi:10.1186/1751-0147-51-3

Aim

The overall aim of this study was to compare causes of mortality in different housing systems for commercial laying hens.

Methods

The study used post mortem findings from 914 laying hens submitted for necropsy between 2001 and 2004 in Sweden. The design was accordingly a retrospective study examining the probable causes of mortality (occurrence of diseases and cannibalism), analysed in terms of the effects of different housing systems. Using the number of disease outbreaks in caged flocks as the baseline, the expected number of flocks with a certain category of disease in the other housing systems was estimated and tested for significant differences based on the observed data.

Main findings

(i) The common causes of mortality in laying hens included colibacillosis, erysipelas, coccidiosis, red mite infestation, lymphoid leukosis and cannibalism.

(ii) Hens from housed litter-based systems and free range operations were over-represented in the post mortem sample compared with hens from cages.

(iii) There was a higher occurrence of bacterial and parasitic diseases and cannibalism in laying hens kept in litter-based housing systems and free range systems than in hens kept in cages.

(iv) The occurrence of viral diseases was significantly higher in indoor litter-based housing systems than in cages.

Authors' conclusions

Layer hens housed in free range and indoor litter-based housing systems were at higher risk of infectious diseases and cannibalism compared with laying hens in cages.

Values-related components

(i) This study prioritises mortality as the key measure on which to base analysis of comparative hen welfare and health in different types of housing systems, as opposed to affective states or some other metrics.

(ii) Hence there is a focus on death rather than suffering during life.

(iii) Taken with the papers studying motivated behaviours (summarised in Appendix 1 above), key value conflicts and questions arise with trade-offs, such as balancing some welfare attributes (e.g. opportunity for behavioural expression) against others (such as higher health outcomes).

Summary of key literature on bird health

Bird health and animal welfare

(i) It is broadly accepted that animal health is an intrinsic component of an animal's welfare, however, other components such as animal affective state and ability to access preferred social and behavioural resources are also considered important.

(ii) Mortality can be used as the ultimate indicator of bird health (and welfare), but its use as a crude measure is criticised as ignoring the larger numbers of birds that may suffer but not actually die.

(iii) Thus, drilling down to identify the causes of mortality, or measuring rates and causes of morbidity, provide better information about welfare status.

(iv) Emerging from the key publications studied in this paper is a clear value conflict, in that bird health appears to be best protected in housing systems that do not generally provide for expression of a wide suite of natural behaviours.

Comments on the key papers

(i) The study by Fleming et al. (2004) used a range of anatomical and pathological measures to assess keel bone integrity. Although not measured directly, it is presumed that significant bone pathologies, such as healing fractures, are likely to be painful.

(ii) The paper by Fleming et al. (2006) used a greater range of measures of bone integrity, including collagen biochemistry and bone ash and mineral content. In contrast to the previous study (above), birds with more freedom to move had improved inherent bone strength, but this result needs to be interpreted with caution as birds that have more room to be active and to jump and perch are also at greater risk of traumatic injuries from misadventure.

(iii) The study by Fossum et al. (2009) supports the concept that bird health challenges are more easily prevented or managed in more controlled environments, in which bird access to waste, other birds and animals, and sources of microbial contamination, are limited. The study's limitations are that it was retrospective in nature, and the use of mortality as a measure is somewhat crude. The authors did use the post mortem examinations to identify the causes of death, which is better than just measuring mortality.

6.3 Appendix 3 – Stress

Beuving G and Vonder GMA (1978) – Effect of stressing factors on corticosterone levels in the plasma of laying hens.
General and comparative endocrinology 35, 153-159

Aim

Assessing the effect of ACTH challenge and various other stressful stimuli on plasma corticosterone levels.

Methods

An experimental line of White Leghorn hens, housed in individual cages, was used for the experiment. A group of birds comprising of old laying hens, old rooster and young laying hens was used for ACTH challenge. Blood samples were collected at regular intervals from a wing artery between T0 and 120 minutes post ACTH injections. Other stressors imposed on birds were: handling stress imposed by hand immobilisation, crating birds with no access to food or water, heat stress imposed for 1 hour, food deprivation for 5 days along with water withdrawal for 2.5 days. Corticosterone was measured in the plasma using competitive protein binding assay in individual collected samples.

Main findings

(i) ACTH injection increased corticosterone concentration considerably within a few minutes in all treatment groups. The response was greater in younger hens compared to older, however, corticosterone remained high for a longer period of time in older hens. Overall, the same average maximum corticosterone levels were achieved by hens in each treatment group. Most importantly, within 3.5 minutes after ACTH challenge, corticosterone levels were already significantly higher than baseline levels.

(ii) Immobilisation by hand caused a significant increase in corticosterone after only 45 seconds from the start. There were individual variations in the response to immobilisation, where some birds barely had any response to this stressor. During prolonged immobilisation for 1 hour there was a rapid increase in corticosterone within 5 minutes of the start, which was followed by a slower increment throughout the duration of 1 hour. Corticosterone levels were significantly higher than the baseline for all time points during 1 hour of imposed treatment.

(iii) Repeated handling of 4 times per day for 5 days significantly increased mean corticosterone in the first period of handling. The levels of corticosterone did not decrease significantly for all 5 days of imposed treatment.

(iv) Significant increase in corticosterone was seen crating 15 birds together. No adaptation to immobilisation was found.

(v) Deprivation of water had more significant effect on corticosterone than starvation. The levels of corticosterone returned to a normal range after the birds were given back water.

(vi) Heat stress caused an initial increase in corticosterone levels, however, there was no difference in hormone values for the subsequent days.

Authors' conclusions

Deprivation of food and water as well as heat stress are regarded as severe stressors, however, the

results of this study did not support this belief. Overall, immobilisation either by hand or crate for short or prolonged periods of time had the most significant effect on corticosterone levels. Corticosterone in blood plasma may be a good marker of stress after a particular stimulus. However, the outcome of this study showed that consistency of the response must be tested for each stressor individually.

Values-related components

This study relies solely on corticosterone to measure stress, instead of using a range of measures, and hence defines stress in a fairly narrow manner.

Gross HB and Siegel HS (1983) – Evaluation of the Heterophil/Lymphocyte ratio as a measure of stress in chickens.
Avian diseases 27, 972-979

Aim

Assess the effect of various stressors on heterophil/lymphocyte (H/L) ratio in chickens and determine the effects of dietary supplementation of corticosterone on H/L ratio.

Methods

White Leghorn birds from high and low antibody producing lines and from high (HC) and low (LC) corticosterone producing lines were used for the study. Corticosterone was mixed in their feed and given for 1 day before blood collection. Two methods were used to validate H/L ratio: hemocytometer and the stained-slide method. Plasma corticosterone was measured using a competitive binding assay. Various stressor treatments imposed on chickens were: fasting for 2 days, dietary supplementation of corticosterone, intravenous inoculation with *E. coli* 24 hours before blood collection.

Main findings

(i) Both H/L ratio and plasma corticosterone levels increased with the increasing dietary corticosterone. The best correlation between H/L and plasma corticosterone was seen in well socialised groups that had stable social hierarchy before any experimental procedure.

(ii) Interestingly, there was no difference in corticosterone response of HC and LC selected line of birds to imposed social stress but, birds from both lines had distinctly different H/L ratios under imposed treatments.

(iii) Of all the imposed treatments, significantly high H/L ratio was seen in the following treatment groups: fasting, dietary supplementation of corticosterone, IV inoculation by *E.coli*, social stress imposed on birds from high-corticosterone response genetic line, after vaccination against Newcastle disease.

Authors' conclusions

The authors concluded that since social rank and social stress influences H/L ratios, they might be valuable measures to support behavioural observations. The H/L is a good measure of environmental stress in chickens.

Values-related components

This study relies solely on H/L ratio to measure stress, instead of using a range of measures.

El-Lethey H, Aerni V, Jungi TW, Wechsler B (2000) – Stress and feather pecking in laying hens in relation to housing conditions.
British poultry science 41, 22-28

Aim

To assess physiological stress in hens housed without access to straw as foraging material and in the hens that were fed pellet feed.

Methods

White laying hens of Leghorn hybrid strain were used in the study without having their beak trimmed. Birds in the foraging treatment group were provided long-cut straws as bedding on a section of the pen floor. To avoid unnecessary pain all injuries caused by feather pecking were treated, which stopped hens from further pecking the wounds. Feather pecking was assessed using the previously published method (Aerni et al. 2000). Stress physiology was measured using Heterophil/Lymphocyte (H/L) ratios, tonic immobility (TI), antibody production against human serum albumin (HSA), tetanus toxoid (TT), sheep RBCs. Only 1 bird from each treatment group was bled in order to minimise overhandling.

Main findings

(i) Feather pecking data obtained from the Aerni et al. 2000 study showed that birds housed without straw and fed pellets had the highest rate of feather pecking.

(ii) The number of attempts needed to obtain TI were not different in any treatment groups, however, birds housed without straw and fed pellets had significantly higher duration of TI compared to those housed with straw and fed on mash.

(iii) H/L was significantly higher in hens housed without straw and those fed on a pellet diet.

(iv) Hens housed with straw had significantly high antibody titre to both sheep RBC and TT antigens compared to the hens housed without straws. The antibody titre against sheep RBC was highest 5 days post immunisation, whereas antibody titre against TT was highest on day 8 and day 11 post immunisation. There was no difference in antibody titre against HSA for any treatments.

Authors' conclusions

The authors of this study conclude that provision of foraging material and the form of feed have a significant effect on feather pecking and physiological markers of stress, suggesting that feather pecking in laying hens is associated with stress.

Values-related components

(i) This study assumes increased risk of birds to feather pecking when deprived of foraging opportunities based on previous studies.

(ii) It also assumes that birds fed pellets had greater tendencies to perform feather pecking than birds fed mash feed.

Tilbrook AJ, Ralph CR (2018) – Hormones, stress and the welfare of animals. Animal production science 58, 408-415

Aim

This review discusses the limitations of using endocrine measures in the assessment of animal welfare and proposes future research that may improve our knowledge in this area.

Methods

The authors give a general overview of stress and animal welfare, followed by discussion on the involvement of the endocrine system in stress response and how it affects the welfare of an animal. The authors then conclude the review by suggesting areas of research that may reduce our knowledge gap in using hormones as a measure to assess stress.

Main findings

(i) Stress is a very complex term to define, and both the emotion and subjectivity associated with the word make it harder to understand its exact meaning.

(ii) The working definition of 'stress' proposed by the authors is "a complex physiological state that embodies a range of integrative and behavioural processes when there is a real or perceived threat to homeostasis" (Tilbrook & Clarke 2006, Tilbrook 2007).

(iii) Hormone levels alter either in direct or indirect response to stress (Matteri et al. 2000), and it is typical of researchers to measure hormone level in order to assess stress. In particular, sympathoadrenal system and the HPA axis are considered as frontline physiological responses during stress.

(iv) Hormones such as the catecholamines and glucocorticoids are involved in a range of biological processes that are beyond stress and have little effect on the welfare of animals. Furthermore, the stress response in each animal is confounded by gender, past experience, genetic and environmental factors, physiological state, seasonal and diurnal changes (Moberg 2000, Tilbrook & Clarke 2006).

(v) It is important to understand the downstream effect of endocrinal changes in response to stressors, to accurately ascertain its effect on the welfare of animals. In other words, increase in circulating levels of endocrine hormones doesn't always mean that the welfare of animals is compromised.

(vi) A generalised stress response is required to maintain homeostasis in an animal and the presence of such response may simply mean that an animal's body is functioning well and therefore its welfare is not compromised. For example, even though an increase in corticotropin-releasing hormone (CRH) leads to activation of HPA axis and ultimately results in increased secretion of glucocorticoids, these neuropeptides also have a more central role in regulating various functions of brain (Tilbrook, 2007).

(vii) Furthermore, a cautionary approach needs to be taken while interpreting the results of circulating levels of hormones (e.g. glucocorticoid in plasma), as the same hormone can have different physiological effects to different stressors at different times.

(viii) There are different consequences of actions of glucocorticoids, even when the mechanism of action at cellular levels remain the same (Sapolsky 2000, Sapolsky et al. 2000). For instance, acute change in glucocorticoids may activate the immune system, however, chronic increase in glucocorticoids supresses the immune system making animals susceptible to diseases (Selye 1955b, Sapolsky 2000, Sapolsky et al. 2000).

(ix) A systematic research to determine the actions of hormones and their consequences to specific stressors under particular conditions will help in the understanding of the overall effect of these changes on the welfare of an animal.

Authors' conclusions

The authors conclude that even though it is a common practice to measure hormone levels in order to understand stress and welfare in animals, many of the findings are inconclusive due to the complexity associated with the functioning of endocrine systems. Furthermore, it is difficult to separate the hormonal changes in response to stress as just a consequence of normal biological functioning. The credibility of endocrine measures is dependent on whether the authors have looked at how the stressor is received by an animal and how that in turn affects the synthesis, secretion, storage, transport and action of hormones, and eventually the downstream physiological and behavioural changes brought about by the hormones.

Values-related components

This paper seeks to establish a new and more complex definition of 'stress,' and in doing so adopts a number of implicit value assumptions about the complexities of the endocrine system and its relation to stress.

Summary of key literature on stress

Although routinely used as a measure of negative state in animals, stress does not have a unified definition or aetiology. Moberg (2000) divided overall stress response into two categories: non-threatening stress response, which is often part of normal biological response to restore homeostasis; and a state of distress where prolonged biological response to stress has deleterious effect on animals' welfare. The biggest challenge for scientists has been to find physiological markers that are distinctive for stress and distress. Scientists in both human and animal research have used a wide range of physiological systems such as endocrinal, behavioural and immunological systems as indicators of stress. However, none of the markers used so far can reliably measure stress under all conditions, one of the biggest confounding factors being the interpretation of the physiological changes (Cook et al. 2000). A model of animal stress by Moberg (1999) gives a breakdown of stress response in an animal when challenged with a stressor (Figure 1). According to the model the stress response begins with recognition of a stressor, followed by biological response to the stressor and finally the downstream effect of the stress response. It is only the final stage of the biological response that determines whether the welfare of an animal is compromised. However, current technical knowledge makes it challenging to assess all the stages of the stress response system. In conclusion, early researchers demonstrated that the biological response of an animal varies depending on the stressors and therefore it might be valuable to have a specific measure for each type of stressor (Mason 1968, 1975).

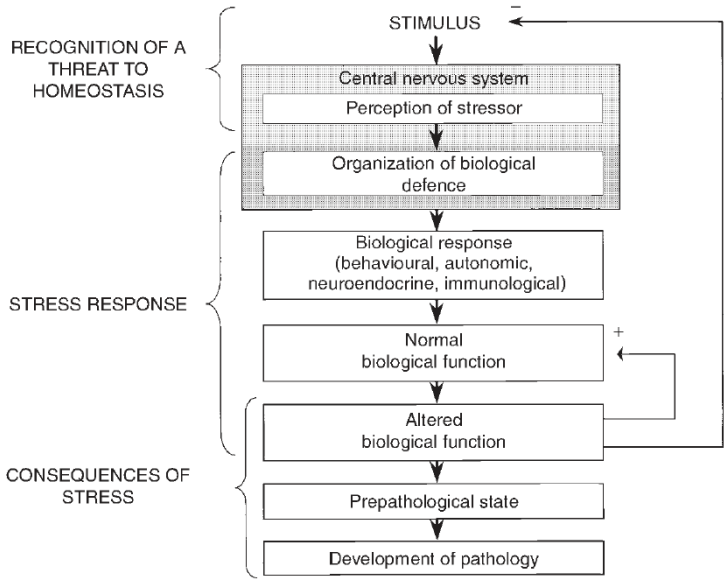

Figure 2 Animal model of stress response (Moberg 1999)

Comments on the key papers

(i) The Beuving and Vonder (1978) paper is one of the pioneering pieces of research validating the use of corticosterone to measure stress following exposure to various environmental and biological stressors. This paper has formed the basis for many subsequent studies looking at stress physiology in laying hens. It is evident from the findings of this study that corticosterone response to each stressor varies in magnitude and duration. Indeed, Koolhaas et al. (2011) reported that corticosterone is secreted to a varying degree in response to negative as well as positive stimuli such as arousal and eating. Furthermore, corticosterone is secreted at a basal level throughout the day (Breuner et al. 2013) and hence, rather than measuring an absolute value, it is critical to look at corticosterone over time and expressed as relative change to individual's baseline levels. Consequently, by looking at the localised effect of corticosterone on the target tissues we may be able to improve our knowledge of the role of corticosterone in the presence of a particular stressor (Freire & Cowling 2013, Rodenburg et al. 2008, Lay et al. 2011). Finally, when evaluating stress, it is prudent not to rely solely on corticosterone, but instead to use a range of measures to get accurate results (Ralph et al. 2015).

(ii) Gross and Siegel (1983) is one of the earliest studies to propose the use of the heterophil/lymphocyte (H/L) ratio as a physiological marker of stress. One of the most important aspects of this study is that they tested changes to H/L by imposing a variety of biological and environmental stressors. An important finding of this study was the influence of social ranking and social stress on H/L ratio, indicating that it can be a valuable tool for studies that use social stressor as their treatment. Overall, the study was able to demonstrate that H/L ratio can be used as a reliable marker of stress caused by a range of stressors and may be less variable than corticosterone.

(iii) The authors of El-Lethey et al. (2000) proposed that the increased risk of birds to feather peck when deprived of foraging opportunities and fed a pellet diet was due to underlying stress. This value-based assumption was tested in previous studies that found a correlation between feather pecking and foraging opportunities (Hughes & Duncan 1972, Blokhuis 1986, Huber-Eicher & Wechsler 1997). The study was also based on value-based assumptions that birds fed pellets had a greater tendency to perform feather pecking than birds fed mash feed

(Bearse et al. 1949, Walser 1997). The study had a small sample size and they used only one strain of birds, limiting their ability to provide any generalised conclusions. There was further reduction in the sample size, while measuring antibody titre as only one bird was picked from each pen for blood collection. Such a small sample size may reduce the accuracy of the results. Nonetheless, this study is important in improving our understanding of the various physiological measures of stress in laying hens, and highlights the importance of sampling time, especially when it comes to blood collection for antibody titre post-immunisation. A larger-scale study with a bigger sample size and different strains of birds, particularly ones genetically selected for high-feather pecking and low-feather pecking, would be very informative, especially with regards to understanding the relationship between strain-specific feather pecking and physiological markers of stress.

6.4 Appendix 4 – Housing systems

Sherwin CM, Richards GJ, Nicol CJ (2010) – Comparison of the welfare of layer hens in 4 housing systems in the UK.
British Poultry Science 51, 488-499

Aim

Assess the welfare of hens in 26 UK flocks (6 conventional cage, 6 furnished cage, 7 barn, 7 free range) throughout the laying period. The strains of birds housed in this study were: Lohmann, Hisex, Hy-Line and Isa Brown in conventional and furnished cages; Hy-Line in barns; and Hy-Line and Lohmann in free range.

Methods

(i) The researchers used a combination of behavioural (pecking, perching, and vocalisations), stress physiology (faecal corticosterone, eggshells with calcification spots and blood stains) and health (skin and plumage damage, keel fractures) measures as well as body weight and mortality to assess hen welfare.

(ii) Behaviours examined by the researchers during three visits to each flock included occurrence of injurious behaviours (gentle feather pecks (received or given), aggressive pecks (received or given), severe feather pecks (received or given), and cannibalistic pecks (received or given)), vocalisations indicative of frustration ('gakel' calls) and perch use), physiology (faecal corticosterone concentrations), and physical health (feather and skin damage; and indicators of general health, such as body weight, posture and abnormal scratching).

(iii) Health from post-mortem analysis (150 hens from each flock at the end of the laying period) conducted by the researchers – beak deformities, skin damage, parasites, plumage damage, plumage soiling, vent damage (not from pecking), evidence of vent pecking, foot condition (including bumble-foot), keel protrusion, keel deformation, and fractured keels.

(iv) Weekly information on health, stress and behaviour submitted by producers, including mortality, the prevalence of red-mites, the proportion of eggshells with calcification spots (100 eggs per week), the proportion of eggshells with blood stains (100 eggs per week), and the number of hens performing injurious pecking.

Main findings

(i) The housing system affected several of the welfare indicators recorded by researchers on farm: gentle feather pecks, feather damage score, the proportion of hens with feather damage, body weight, and faecal corticosterone concentration (Table 1). The frequency of gentle feather pecks and faecal corticosterone concentrations was lower in conventional cages and furnished cages. The feather damage score and the percentage of hens with feather damage were higher in conventional cages, furnished cages and barns. While perches were not available in conventional cages, the percentage of hens using perches was higher in furnished cages than in barns and free range. Hens in barns had the lowest body weight, and hens in conventional cages were heavier than those in furnished cages but not those in free range.

(ii) Post-mortem analysis revealed several differences between housing systems in skin damage, plumage damage, keel protrusion, vent injuries and old and recent keel fractures (Table 1). The percentage of hens with old keel fractures and the percentage of hens with vents pecked

were lower in conventional cages and furnished cages, while the percentage of hens with recent keel fractures was higher in conventional cages. Furthermore, skin and plumage damage scores indicated that less skin damage occurred in conventional cages and furnished cages, and less plumage (vent and abdomen) damage occurred in conventional cages, furnished cages and free range.

(iii) There was an effect of housing system on the temporal change in the proportion of hens found dead, as recorded by producers. Overall, all the four housing systems showed an increase in mortality rate with age, with the highest hen mortality in barns and the lowest in furnished cages (Figure 3). The percentage of hens with red-mite was highest in conventional cages (Figure 4). The percentage of eggshells with calcification spots was highest in conventional cages and free range, and the percentage of eggshells with blood stains was highest in barns and lowest in conventional cages and furnished cages.

Table 1 Significant housing effects

	Housing system			
Measures	**CC**	**FC**	**Barns**	**FR**
Recorded on farm by researchers				
Gentle feather pecks	0.01^{a}	0.06^{a}	$\mathbf{0.16^{b}}$	$\mathbf{0.38^{b}}$
Perch use (% hens)	n/a	$\mathbf{26.6^{b}}$	2.1^{a}	2.5^{a}
Feather damage score	$\mathbf{0.5^{b}}$	$\mathbf{0.5^{b}}$	$\mathbf{0.5^{b}}$	0.3a
Flocks with feather damage (%)	$\mathbf{24.7^{b}}$	$\mathbf{24.9^{b}}$	$\mathbf{26.9^{b}}$	15.5a
Body weight (kg)	1.95^{ab}	1.80^{cd}	$\mathbf{1.72^{d}}$	1.86^{abc}
Faecal corticosterone (ng/g)	14.0^{a}	10.7^{a}	$\mathbf{21.8^{b}}$	15.6^{ab}
Recorded post mortem by researchers				
Skin damage score*	0.59	1.05	1.31	1.68
Plumage damage (vent, abdomen scores)*	1.96	2.19	2.55	2.15
Hens vent pecked (%)	6.2^{a}	1.6^{a}	10.0^{ab}	$\mathbf{22.5^{b}}$
Hens with old keel fractures (%)	17.7^{a}	31.7^{a}	$\mathbf{69.1^{b}}$	$\mathbf{59.8^{b}}$
Hens with recent keel fractures (%)	$\mathbf{24.6^{b}}$	3.6^{a}	1.2^{a}	1.3^{a}
Producer records				
Weight of hens found dead (kg)	1.87	1.58	1.66	1.77
Eggshells with calcification spots (%)*	3.5	1.2	4.1	1.7
Eggshells with blood stains (%)*	1.0	0.8	2.1	1.4

Means within columns with different superscripts differ significantly ($P < 0.05$).
* Significant X^2 value showing significant ($P < 0.05$) housing effects.

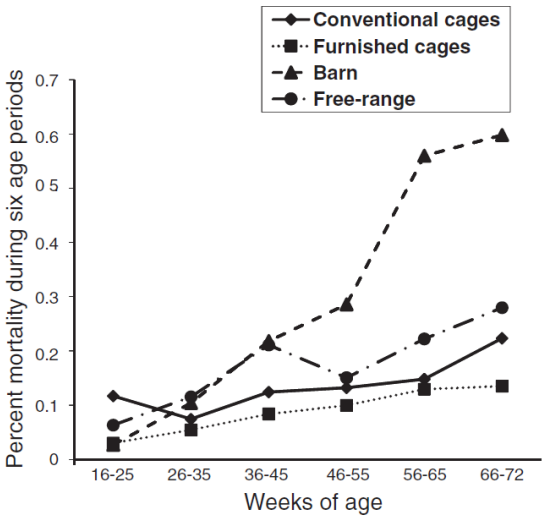

Figure 3 The proportion of hens placed found dead throughout the laying phase in four different housing systems, as reported by producers in weekly questionnaires

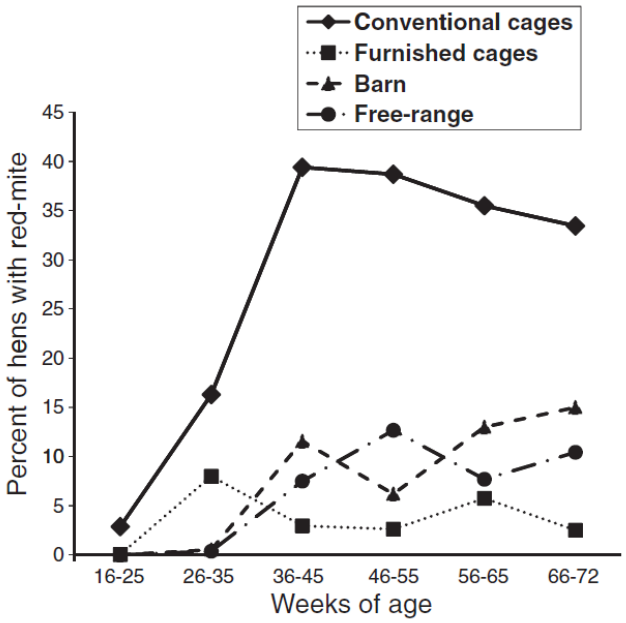

Figure 4 The percentage of hens with red-mite throughout the laying phase in four different housing systems, as reported by producers in weekly questionnaires

Authors' conclusions

Each housing system had positive and negative aspects. Overall, hens in barn systems had the highest prevalence of poor plumage condition, old fractures, emaciation, abnormal egg calcification, and the highest corticosterone concentrations. Hens in conventional cages sustained more fractures at depopulation than birds in other systems. Vent pecking was most prevalent in free range flocks. The lowest prevalence of these problems occurred in hens in furnished cages. Although housing system had an influence on the hens' physical condition and physiological state, the high prevalence of emaciation, loss of plumage, fractures and evidence of stress is of concern across all housing systems and suggests that the welfare of modern genotypes is poor.

Values-related components

(i) Choice of measures associated with welfare necessarily involves values in terms of what is thought to be most important, and also what can be measured and how.

(ii) This study conflates the housing system with the location, hence revealing certain values underlying the original experimental set-up.

Koelkebeck KW, Amoss MS, Cain JR (1987) – Production, physiological, and behavioral responses of laying hens in different management environments.
Poultry Science 66, 397-407

Aim

The authors used production, physiological, and behavioural data to develop an integrated assessment of the response of laying hens to different housing systems.

Methods

Seven hundred and forty-eight commercial Comb White Leghorn pullets were housed at 22 weeks of age in two housing systems, conventional cages and floor pens with litter, in two poultry facilities. Twelve cage treatments consisted of housing three, four, or five hens in deep and shallow cages of different dimensions, which provided floor space allowances of 350 and 460 cm^2/hen. Four floor treatments housed 35 hens or 32 hens and three roosters at densities of 940 or 373 cm^2/bird, in two replicated pens each. Quantitative data were collected simultaneously for 23 production, physiological, and behavioural characteristics throughout the study.

The main measurements used by the researchers were:

(i) Behaviour – observations conducted in 10-min observation sessions for 5 h at 15-s (cages) or 30-s (pens) intervals to record occurrence of feeding (eating or pecking at feed), drinking, preening, moving, standing, crouching, feather pecking, litter pecking, roosting, and nesting.

(ii) Physiology – plasma corticosterone, triiodothyronine and thyroxine concentrations, and heterophil/lymphocyte ratio were measured in one randomly selected hen in each of four cages per treatment and four randomly selected hens from each floor pen. Furthermore, the corticosterone response to an ACTH challenge of eight randomly selected hens from each treatment was measured, and an assessment of packed red blood cell volume and the response to a *S. pullorum* challenge were determined for other hens in each treatment.

(iii) Physical condition – feather condition of all hens was scored.

(iv) Production – egg production and feed conversion were recorded daily.

Main findings

(i) When comparing all caged hens with floor pen hens, caged hens had better egg production rates and better feed efficiency (Table 2); they also gained more weight, and had greater egg and eggshell weights than floor pen hens.

Table 2 Main significant housing effects (Koelkebeck et al. 1987) – statistical analysis conducted on the combined average of all cage or floor treatments

	Housing system	
Measures	**Cages**	**Floor pens**
Production and Health		
Feed conversion*	1.89^{x}	2.03^{y}
Hen-day egg production (%)	76.3^{b}	73.9^{a}
Mortality (%)*	95.0^{x}	98.9^{y}
Behaviour		
Drinking (% hens observed)	4.7^{a}	5.7^{b}
Preening (% hens observed)	10.4^{b}	7.6^{a}
Moving (% hens observed)	4.0^{x}	8.0^{y}
Standing (% hens observed)	32.2^{y}	14.3^{x}
Crouching (% hens observed)	11.2^{b}	4.2^{a}
Feather pecking (% hens observed)	1.28^{b}	0.30^{a}
Physiology		
Plasma corticosterone (pg/ml)	445.4^{x}	595.0^{y}
Plasma corticosterone response to ACTH challenge (ng/ml)	14.6^{x}	21.3^{y}
S. pullorum titres	1372.3^{y}	834.7^{x}

^{a,b} and ^{x,y}: means within rows with different superscripts differ significantly ($P < 0.05$ and $P < 0.01$, respectively).
* Significant X^2 value showing significant ($P < 0.05$) housing effects.

(ii) All floor pen hens had higher viability, higher plasma corticosterone concentrations, a greater response to an adrenocorticotropin (ACTH) challenge, and lower antibody titres to *Salmonella pullorum* challenges than all caged hens.

(iii) Caged hens preened, stood, crouched, and feather pecked more than floor hens, while floor hens drank and moved about more than caged hens.

Authors' conclusions

Integration of all measurements indicates that properly managed caged hens were subjected to significantly fewer stressors than laying hens housed in floor pens, although the hens' wellbeing in the two environments could not be quantitatively compared.

Values-related components

(i) Again, in this study, choice of measures associated with welfare and their interpretation necessarily involves values in terms of what is thought to be most important and also what can be measured and how. This study also conflates the housing system with the location, hence revealing certain values underlying the original experimental set-up.

(ii) The use of production metrics as the essential measures of outcomes might be viewed as prioritising attributes associated with increased or efficient production over more affective attributes associated with animal welfare.

Shimmura T, Hirahara S, Azuma T, Suzuki T, Eguchi Y, Uetake K, Tanaka T (2010) – Multi-factorial investigation of various housing systems for laying hens.
British Poultry Science 51, 31-42

Aim

The researchers evaluated the welfare of laying hens in housed in conventional cages, furnished cages, aviaries and free range systems.

Methods

284 medium hybrid laying hens (a White Leghorn/Rhode Island Red cross-breed) studied in 6 housing treatments: small (450 cm^2/hen, group size of 2 hens) and large (600 cm^2/hen, group size of 2 hens) conventional cages ('SC' and 'LC'), small (605 cm^2/hen, group size of 20 hens) and large (658 cm^2/hen, group size of 54 hens) furnished cages ('SF' and 'LF'), single-tiered aviary (720 cm^2/hen, group size of 18 hens; 'SA') and free range (2.5 m^2/hen, group size of 18 hens; 'FR').

The main measurements used by the researchers were:

(i) Behaviour – instantaneous point sampling at 10 min intervals for 4 h in each of 3 days in 6 weeks from 22-63 weeks of age was used to assess the occurrence of comfort (dust-bathing, stretching, tail flapping, wing-flapping), aggressive pecking, severe feather pecking, litter-scratching, sham dust-bathing, moving, and pre-laying activities. Tonic immobility testing on 72 hens was also conducted at 45 weeks to measure general fearfulness (duration of tonic immobility).

(ii) Physiology – the heterophil/lymphocyte ratio was measured in blood samples from 48 hens at each of 3 ages.

(iii) Production – egg production and mortality were recorded daily.

(iv) Physical condition – body weight was measured, and feather condition and foot condition (inflammation) were scored on 72 hens at 3 ages.

Main findings

(i) Housing system affected both hen mortality and foot condition with mortality lowest in hens in small conventional cages, large conventional cages and small furnished cages. Foot damage was greatest in hens in to aviaries and free range.

(ii) Housing system affected hen behaviour with more hens performing wing-flapping in free range than small aviaries, and in small aviaries than in other systems. More hens performed tail-flapping in free range and small aviaries than in small conventional cages.

(iii) More hens performed dust-bathing in small furnished cages than in large furnished cages and free range, and more performed sham-dust-bathing in the conventional cages than in the furnished cages. More hens were moving in free range than in small aviaries, in small aviaries than in the furnished cages, in furnished cages than in the conventional cages, and in large conventional cages than in small conventional cages. More hens performed litter scratching in free range than in small aviaries, and in small aviaries than in the furnished cages.

(iv) The duration of tonic immobility was longer in hens in the cage systems than in hens in free range.

(v) Housing system affected the heterophil/lymphocyte ratio: it was higher in hens in conventional cages than in hens in aviaries and free range. More details of results are shown in Table 3.

Authors' conclusions

The non-cage systems, especially free range, score poorly for freedom from pain, injury, and disease. Conversely, the scores for the freedom to express normal behaviour and immune response were high in the non-cage systems. The reverse situation was found in the conventional cages. Among the furnished cages, behaviour was more diverse in small furnished cages than the large furnished cages, and immune response of small furnished cages was comparable with the non-cage systems.

Table 3 Main significant housing effects

	Housing system					
	CC[1]		FC[2]		Aviary	Free range
Measures	**Small**	**Large**	**Small**	**Large**		
Health						
Feather damage score	3.4[a]	2.9[a]	4.0[ab]	4.2[ab]	6.7[a]	5.6[b]
Foot damage score	1.0[a]	1.0[a]	1.1[a]	1.0[a]	1.2[b]	1.6[b]
Mortality (%)*	0.0	0.0	0.0	2.8	5.6	6.9
Behaviour						
Wing-flapping (%)	0.0	0.0	0.0	0.0	0.3[a]	0.5[b]
Tail-flapping (%)	0.0[a]	0.0[ab]	0.0[ab]	0.0[ab]	0.1[b]	0.1[b]
Dust-bathing (%)	-	-	4.7[b]	2.1[a]	3.6[ab]	2.4[a]
Sham-dust bathing (%)	2.8[b]	2.8[b]	0.3[b]	1.3[b]	-	-
Moving (%)	0.1[a]	0.8[b]	2.5[c]	3.5[c]	6.5[b]	11.8[a]
Pre-laying (%)	-	-	1.4[a]	3.1[a]	6.9[b]	6.0[b]
Litter scratching	-	-	0.1[a]	0.1[a]	0.7[b]	2.3[c]
Feather pecking (%)	0.4[a]	2.9[a]	4.0[ab]	4.2[ab]	6.7[b]	6.5[b]
Aggressive pecking (%)	0.2[a]	0.2 [a]	0.3[a]	1.6[c]	0.6[b]	0.2[a]
Tonic duration (s)	713.2[b]	6.27[b]	591.8[b]	430.6[a]	375.6[ab]	157.8[a]
Physiology						
H/L ratio	0.3[b]	0.3[b]	0.2[a]	0.2[ab]	0.2[a]	0.2[a]

[1] and [2]: CC denotes conventional cages, and FC denotes furnished cages.
Means within rows with different superscripts differ significantly ($P < 0.05$).
* Significant X^2 value showing significant ($P < 0.05$) housing effects.

Values-related components

Again, in this study, choice of measures associated with welfare necessarily involves values in terms of what is thought to be most important and also what can be measured and how.

Weeks CA, Lambton SL, Williams AG (2016) – Implications for welfare, productivity and sustainability of the variation in reported levels of mortality for laying hen flocks kept in different housing systems: A meta-analysis of ten studies.
PLoS ONE

Aim

The relevant aim in this paper in terms of hen welfare was to examine the impact of on-farm cumulative mortality (CM) using data from European producer records for commercial flocks kept in different housing systems.

Methods

Data from ten sources (raw data from ten published and unpublished studies – approximately 45 million laying hens in 3,851 flocks) were modelled to identify variation in levels of mortality in laying hens. Independent variables examined to predict mortality were time of year, age flock size, housing system (conventional cages, furnished (colony) cages, aviary, barn, free range and free range aviary). All models included the time of year at which the cumulative mortality data were collected. The explanatory variables: age; flock size; house type; breed; beak trim and organic status were each entered individually into the model to produce bivariable models (controlled for time of year as described above). Variables significant in bivariable models were then entered together into a multivariable model; any non-significant variables ($p > 0.05$) were removed and the model was re-run. Thus a final model was produced with only significant variables.

Main findings

(i) All variables show highly significant associations with CM, which increased with age; decreased with flock size; was highest in flocks of intact beaked birds and organic flocks; and varied with both housing system and breed.

(ii) Box plots for mortality in each housing system are presented in Figure 4. Using predictions based on the predominant breed in the dataset, for 1st July, predicted mean CM in a free range flock was 3.9%, 7.4% and 9.3% at 40, 60 and 72 weeks of age, respectively. In comparison, for a flock housed in a conventional cage system, the corresponding mean CM were 1.7%, 4.2% and 5.7%, respectively.

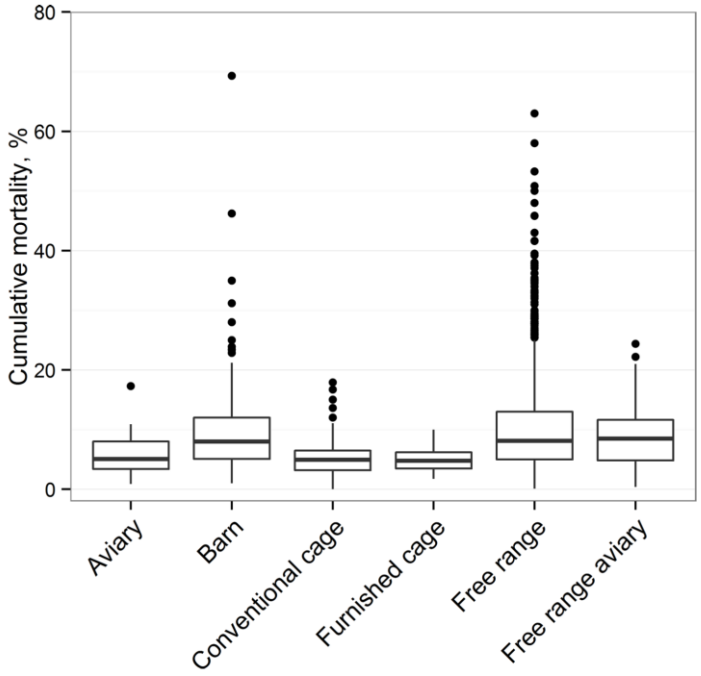

Figure 5 Box plots for mortality in each housing system between 60 and 80 weeks of age using the full dataset from 10 studies (3,851 flocks)

Authors' conclusions

Reducing the high levels of mortality as seen in free range systems would enhance hen welfare and better meet the expectation of egg consumers. More research to understand the genetic x environment interaction and detailed records of the causes of mortality are required so that improved genotypes can be developed for different systems and different breeds can be better managed within systems.

Values-related components

This study makes a range of assumptions about the expectations of egg consumers, in part through a narrow focus on mortality rather than including consideration of more affective aspects of animal welfare as well as other health-related aspects of welfare short of death.

Summary of key literature on housing systems

Housing systems and animal welfare

(i) It is widely accepted within science that there is no single measure of welfare. Information using a variety of indicators of health, physiology and behaviour are required and this information has to be combined to draw overall conclusions about the benefits and drawbacks of different housing systems (Dawkins 2003, Nicol et al. 2006). Furthermore, these indicators may not co-vary, some may be more valid than others and, as yet, there is little agreement between researchers on the specific weightings that should be assigned to each indicator (Nicole et al. 2006).

(ii) Field studies as well as laboratory studies are important in understanding the welfare implications of housing systems because it is difficult to replicate the scale or size of commercial systems in a laboratory (Lay et al. 2011).

(iii) Evaluating housing systems is complicated because of integral differences in climatic and social environments, genetics, nutrition, and management of each housing system. Comparing data across studies also adds complexity because of potentially confounding differences in environment, genetics, nutrition, and management (Lay et al. 2011). These comparisons of housing systems are further complicated if they involve the use of individual farms or sites for each replicate of a housing system. Due to the large number of animals required, and the specific requirements of each housing system in terms of climatic and social environments, nutrition and management, it becomes increasing prohibitive with more housing comparisons to house the housing treatments in the one facility.

(iv) As concluded in numerous reviews on farm animal welfare in intensive production systems, specific attributes or design and management of the production system can markedly affect animal welfare (Rushen & Passillé 1992, Lay et al. 2011, Barnett et al. 2001, Rushen 2017, Hemsworth 2018). Indeed, the design and management of any production system are probably more important for animal welfare than is generally recognised.

Comments on the key papers

There is a limited number of peer-reviewed papers comparing the welfare implications of the current housing systems for laying hens.

(i) The first three papers examined here (Sherwin et al. 2010, Koelkebeck et al. 1987, Shimmura et al. 2010), each used a range of welfare indicators to compare the welfare of hens in cage and non-cage systems. In these field and laboratory-based studies, the authors used multiple measures to assess welfare, such as behaviour (e.g. pecking, perching, preening, vocalisations, locomotion, feeding, drinking and litter scratching), stress physiology (e.g. corticosterone concentrations, corticosterone responses to adrenocorticotropin (ACTH) challenges, immune responses, heterophil/lymphocyte ratio, packed red blood cell volume, and occurrence of eggshells with calcification spots and blood stains), and health (e.g. skin and plumage damage, keel fractures, foot inflammation) and other fitness variables (e.g. body weight, feed conversion and mortality). These welfare indicators have been and are currently well-accepted in the scientific literature. The integration of information from multiple measures, and its interpretation in terms of animal perception and emotion, is currently the most appropriate method to judge relative welfare implications of the various housing systems.

(ii) The fourth study, that of Weeks et al. (2016), utilised a meta-analysis of ten studies on reported levels of mortality in commercial laying hen flocks kept in different housing systems to examine the relationships between a number of factors including housing system and hen mortality. As with disease, the implications of the noxious subjective experiences associated with mortality on animal welfare are often not recognised adequately (Broom and Corke 2002). Health and injuries are an important part of welfare and whenever an animal is injured or diseased, welfare is poorer. Similarly, hypothermia, hunger, thirst, sickness and pain associated with mortality are considered potentially noxious subjective experiences (Mellor & Stafford 2004).

(iii) Two of the studies confound housing system with location, raising the possibility of bias in the welfare measurements due to differences in environment, nutrition, and management (Sherwin et al. 2010, Koelkebeck et al. 1987) as well as genetics (Sherwin et al. 2010). Nevertheless, the results of these four studies considered here on cage housing for laying hens are consistent in demonstrating that the welfare risks differ between housing systems and indeed support the view that no single housing system is ideal from an animal welfare

perspective. A summary of advantages and disadvantages of different housing systems is listed in Table 4 below.

(iv) These four key studies highlight the main welfare risks and benefits of the main international housing systems for laying hens, conventional and furnished cages, barns, aviaries and free range:

(a) conventional and furnished cages limit space and movement, and in turn reduce the incidence of old keel fractures, but increase keel fractures during depopulation;

(b) conventional cages do not provide the furnishing to allow perching, dust-bathing and nesting in a nest box;

(c) conventional cages and furnished cages reduce some injurious behaviours such as feather pecking and vent pecking, and thus skin and feather damage;

(d) conventional cages have a higher prevalence of red-mites than in furnished cages and non-cage systems;

(e) conventional cages and furnished cages increase general fearfulness;

(f) hens in conventional cages and furnished cages have lower, but not higher, levels of stress based on glucocorticoid concentrations (both basal and in response to ACTH), and heterophil/lymphocyte ratios than hens in barns, aviaries and free range;

(g) hens in conventional and furnished cages have lower mortality rates than hens in barns, aviaries, free range and free range aviaries;

(h) while public concerns and policy debates often focus on intensive housing systems, research indicates that the design and management of both indoor and outdoor housing systems is probably more important for animal welfare than is generally recognised (Rushen & de Passillé 1992, Barnett et al. 2001, Hemsworth 2018);

(i) as highlighted by Sherwin et al. (2010) and Weeks et al. (2016), the indication of genetic risk factors associated with susceptibility to poor welfare highlights the need for more research to understand genetic and environment interactions on hen welfare.

Table 4 Advantages and disadvantages of different housing systems (Windhorst 2017)

Housing system	Advantages	Disadvantages
Conventional cages	• Low risk of diseases and infection with parasites • Comparatively low mortality • Comparatively low risk of feather pecking and cannibalism • Low risk of bumble-foot • Reduced air pollution	• Very limited available space per hen • Strict limitation of species specific normal behaviour • High risk of bone fractures resulting from osteoporosis during depopulation • Lacking ability to escape from bullying fellow hens
Furnished cages	• Low risk of diseases and infection with parasites • Comparatively low mortality • Higher space availability, especially in colony nest systems, allow fulfilment of some, not all, natural behaviour patterns • Better bone strength • Low risk of bumble-foot	• Risk of increase of feather pecking and cannibalism in non beak-trimmed groups of brown genotypes • Substantial use of perches may result in keel bone damage • Increase of dust resulting from scratch mats and litter provision • Problems of depopulation in large colony nest systems with increased risk of bone fractures
Barn systems without outdoor access	• Higher space availability enables hens to express most species specific normal behaviour patterns • Increased bone strength • Higher space availability enables submissive hens to avoid contacts with aggressive fellow hens	• High risk of parasitic diseases and infections due to contact with faeces • High risk of foot pad dermatitis resulting from wet litter • Increased risk of bone fractures through collision with perches, nests and other amenities • Highly variable risk of feather pecking and cannibalism resulting in high mortality values • Subordinate hens may have limited access to feed and water because of bullying hens • Increase of dust resulting from litter
Barn systems with outdoor access (free range systems)	• Same advantages as in barn systems without outdoor access • Ability to forage and dust bathing in range	• Same as in barn systems without outdoor access • High risk of predation • Increased risk of infections with internal parasites • High risk of introduction of highly infectious diseases through contact with wild birds

6.5 Appendix 5 – Feather pecking and cannibalism

Lambton SL, Knowles TG, Yorke C, Nicol CJ (2010) – The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens.
Applied animal behaviour science 123, 32-42

Aim

Assessing the risk factors affecting the development of feather pecking in free range, organic and barn systems using a prospective epidemiological approach.

Methods

Data were collected from a total of 119 flocks from 62 farms across UK, with a mixture of free range, barn and organic production systems. Details on farm management, environmental conditions and bird behaviour were collected by visiting the flocks once between 20-30 weeks and 35-45 weeks of age. Data collection was done by performing direct observation of birds and farmer interviews. The shed at each farm was divided into 5 distinct areas: slats, litter, nest boxes, perches and verandas. Feather pecking in a marked section, within each area, was recorded using direct observations continuously for 10 minutes, where a pecking bout was defined as a sequence of pecks, and new bout was counted after a gap of 5 s. Feather pecking was classified as gentle feather pecking (GFP) defined as pecking at the tips of feathers, and severe feather pecking (SFP) defined as pulling and often removal of feathers with the receiving bird often displaying fear or avoidance response.

Main findings

(i) According to farmers' reports, an average of 65% of flocks performed feather pecking at some stage during their laying period. During their first visit, the authors found 89.2% of flocks performed GFP and 68.5% performed SFP. On their second visit, the authors found 73% of flocks performed GFP and 85.6% performed SFP.

(ii) A higher rate of SFP increased the likelihood of farmer observing feather pecking, however, the same was not true for GFP.

(iii) Birds that had their beaks trimmed during rearing performed a significantly higher rate of GFP, and it was significantly reduced when high percentage of flocks performed ranging behaviour. GFP occurred at higher rates around slats and nest boxes compared to other areas of the shed. Additionally, GFP was negatively correlated with the age of birds. Other factors such as access to perches to escape from pecking bird and access to straw for foraging significantly reduced the incidences of GFP.

(iv) Retrospective beak trimming increased the rates of SFP, followed by no beak trimming. Rates of SFP were significantly higher when birds were given feed in the form of pellets. Other factors that increased the rate of SFP were, percentage of flock ranging, floor feeding, feather pecking during transfer from rearing facility. SFP was highest in birds on the litter and slats.

(v) There was a positive correlation between SFP at 25 weeks and 40 weeks of age. SFP was significantly higher in flocks where farmers noted feather pecking upon arrival from the rearing facilities.

Authors' conclusions

The authors of this study concluded that gentle and severe feather pecking are affected differently by

the same risk factors, with the only exception being range use, which affected both GFP and SFP equally. Since GFP does not result in plumage damage and cannot be accurately identified by the farmers, it cannot be used as a reliable marker of feather pecking. SFP, on the other hand, has greater economic and welfare implications than GFP. Nonetheless, the presence of GFP in a flock may imply that hens' behavioural needs are not being fulfilled, resulting in development of abnormal behaviours. One of the key findings of this study is the reduction in feather pecking with the increase in range use, and this may be used as a risk mitigation strategy in commercial loose housing farms.

Values-related components

In general, studies on feather pecking and cannibalism tend to seek to mitigate risk through changing environmental conditions rather than considering development or use of different strains, and hence value assumptions are present in the framing of these studies.

Green LE, Lewis K, Kimpton A, Nicol CJ (2000) – Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. Veterinary record 147, 233-238

Aim

Identify and measure associations between feather pecking, disease and farm management practice in laying hens housed in alternative systems in the UK.

Methods

A questionnaire based on epidemiological principals was developed by the authors, with contributions from members of the 'British Free Range Egg Producers Association (BFREPA)and a number of farmers. The initial questionnaire was tested on five farmers and then modified to its final version based on their feedback. Information collected in the questionnaire included incidence of feather and vent pecking, rearing conditions of the flock, housing and nesting facilities, ventilation, temperature, egg quality, feed type and overall flock health.

Main findings

(i) Overall: 46.6% of the farmers reported normal occurrence of feather pecking in all their flocks. However, 56.6% of the farmers reported feather pecking in the last depopulated flock.

(ii) Severity of feather pecking reported by farmers is shown in Table 5.

Table 5 Percentage of farmers reporting feather pecking in the study

Type of feather pecking	Features of feather pecking	Percentage farmers reporting damage
Gentle feather pecking	Pecking conspecifics' feathers	58
Severe feather pecking	Pulling their own feathers	10
	Pulling feathers of conspecific	49
	Damaged feathers	64
	Bald patches	70
	Blood on hens	12
	Eating feathers	17

(iii) The commonly reported locations for feather damage by farmers was back (68%), neck (57%) and tail (55%).

(iv) The median age at which feather pecking started was 40 weeks, and the median age at which death due to feather pecking was reported was 45.3 weeks.

(v) Almost 37.5% farmers reported that they took some measures to reduce the incidence of feather pecking. Of all of the risk mitigation strategies used by farmers, the most common one was dimming lights within the shed.

(vi) Amongst various management factors, the following were associated with increased risk of feather pecking: flock coming to lay at less than 20 weeks of age, flocks from a flat deck housing system, highly compacted litter by the end of lay period, raised floor area in the shed, presence of electric wire, inspection of birds by single stockperson, communal nest boxes and dim lighting in nest boxes.

(vii) Amongst the environmental factors in the shed, the ones that increased the risk of feather pecking were no natural ventilation, the use of roof fans, shed temperature less than 20^0C.

(viii) Dietary factors such as use of chain feed systems, feeder unavailable on all levels, change in diet during lay cycle, and use of bell drinkers were all linked to increased risk of feather pecking.

(ix) When all the recorded factors were put through a large logistic regression model, the three main significant factors that remained significant were: when the flock had birds infected with egg peritonitis or infectious bronchitis, or when less than 50% of birds in a flock used outdoor range on a sunny day.

Authors' conclusions

The authors acknowledged that the low response rate to the questionnaire used in this study could have been due to the length of the survey. Final logistic models found many management factors to have significant associations with feather pecking. Finally, the risk factors identified in this study may not have been causal as both outcomes and risk factors were reported after the feather pecking had developed, making it difficult to ascertain which occurred first.

Values-related components

In general, studies on feather pecking and cannibalism tend to seek to mitigate risk through changing environmental conditions rather than considering development or use of different strains, and hence value assumptions are present in the framing of these studies.

Pötzsch CJ, Lewis K, Nicol CJ, Green LE (2001) – A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking, management and disease.
Applied animal behaviour science 74, 259-272

Aim

Investigate the frequency of vent pecking and its associations with farm management practices and feather pecking.

Methods

A questionnaire asking for information on vent pecking and feather pecking, rearing and housing management, feeding and drinking, house design, and environmental conditions and overall health was sent to farmers via post. This study is an extension of the previous study by Green et al. 2000.

Main findings

(i) About 27.1% of farmers reported vent pecking as a common occurrence in their flocks and 36.9% farmers observed it in their recently depopulated flock.

(ii) Of all the respondents, 69.9% farmers reported to have seen hens peck the vent of their conspecifics, 31.4% reported that hens eat the flesh of others, 54.8% have seen skin around the vent area exposed. Surprisingly, almost 71.2% of farmers reported to have seen blood around the vent.

(iii) Farmers reported that mortality, as a result of vent pecking, was 1.3%.

(iv) A total of 31.7% farmers reported taking preventative measures of which, dim light in the shed was the most commonly used strategy. Furthermore, once the farmers noticed the onset of vent pecking in their flock, 81.8% farmers controlled it with dim lights in the sheds.

(v) The onset of vent pecking and feather pecking were positively correlated, so was their prevalence within a flock. Significantly large number of flocks developed feather pecking followed by vent pecking.

(vi) Significant associations were reported between vent pecking and: flocks that came into lay before 20 weeks of age, the flocks without access to perches, not kept on wooden slats, housed under dim lighting conditions and low stocking density towards the end of lay.

(vii) The three main factors that were significantly associated with vent pecking, in the same way as feather pecking (Green et al. 2000), in a logistic regression model were: lighting of the nest boxes, more than two diet changes, and use of hanging bell drinkers. Lighting in the nest boxes had the strongest association with vent pecking.

Authors' conclusions

The authors concluded that as a cross-sectional study this research cannot determine causation for

feather pecking and vent pecking. The inaccuracy of the responses was compensated by using large number of flocks and variables. The risk factors identified in this study will need to be studied individually in order to establish a more accurate causal pathway for feather pecking and vent pecking.

Summary of key literature on feather pecking and cannibalism

Feather pecking and cannibalism, collectively referred as 'injurious pecking' (Lambton et al. 2013), are one of the most common behavioural problems in modern strains of chicken that have been genetically selected for high production. Associations have been found between severe feather pecking and reduced egg production, and pain and higher rates of mortality (Sedlačková et al. 2004). Although studies have found some association between gentle feather pecking and severe feather pecking, performance of the former during the rearing period is not a predictor of the latter during the laying period (Newberry et al. 2007). Injurious pecking has severe welfare and economic implications for the egg industry, and there is a need for effective preventative measures that do not compromise the welfare of laying hens and that are acceptable to the consumer and community at large.

Comments on the key papers

(i) The Lambton et al. (2010) study validated the beneficial effect of range use in laying hens and further supported the results from Green et al. (2000). Similar to the findings by Blokhuis (1986) and El-Lethey et al. 2010, the current study found reduction in incidences of feather pecking by providing straw as a substrate to perform foraging and exploratory behaviours. Interestingly, unlike some of the other retrospective studies on this topic, the authors of this study record feather pecking events by performing direct observations themselves, which may improve the accuracy of the data. Addition of flocks from a different genetic background may be beneficial to characterise feather pecking further.

(ii) The study by Green et al. 2000 is a comprehensive study identifying a range of risk factors associated with feather pecking. Although the study has the advantage of large sample size, access to farmer details was given by egg retail companies, which might not be a true industry representation. The study may have benefitted from including independent farmers to answer the questionnaire, as this may have provided for a more representative sample of the whole target population. As the farmer responses were in retrospect, it is not possible to make conclusions about the risk factors associated with the initial onset of feather pecking. It might also be interesting to include flocks from a different genetic background in an epidemiological study like this to validate the genetic influence on feather pecking, similar to the one reported by Rodenburg and Koene (2003). Nonetheless, this piece of research has added greatly to our knowledge on feather pecking in loose housing systems and has formed the basis of many studies on this topic. Also valuable is the insight it gives into the management practices that can be implemented to control feather pecking on a commercial farm.

(iii) The study by Pötzsch et al. (2001), being an extension to the one by Green et al. 2000, shares all the study design limitations of the latter. This study used the same questionnaire as the one used by in the Green study, which may have influenced the amount of information received on vent pecking. Furthermore, as vent pecking has substantial health and welfare implications for the bird, it may have been more valuable to perform such a study on flocks from their rearing stage through to the entire lay cycle. It would also be relevant to collect data on the implications of vent pecking.

6.6 Appendix 6 – Beak trimming

Weeks CA, Lambton SL, Williams AG (2016) – Implications for welfare, productivity and sustainability of the variation in reported levels of mortality for laying hen flocks kept in different housing systems: A meta-analysis of ten studies.
PLoS ONE

Aim

The relevant aim in this paper in terms of hen welfare was to examine the relative impact of beak trimming (or no trimming) on cumulative hen mortality across multiple flocks and housing systems.

Methods

Data from ten sources (raw data from ten published and unpublished studies – approximately 45 million laying hens in 3,851 flocks) were modelled to identify variation in levels of mortality in laying hens. Independent variables examined to predict mortality included the practice of beak trimming, time of year, age, flock size, and housing system.

Main findings

(i) The quantitative analysis of mortality data from 801 beak trimmed and 228 intact-beak flocks housed between 2006 and 2012 found significantly (but not dramatically) lower mortality in the beak trimmed flocks at 40 weeks and at 70 weeks, using a model that accounted for many other bird and management variables. Cumulative mortality was higher in flocks with intact beaks.

(ii) At 40 weeks of age the most common intact beak breed in this dataset, kept in a free range system, had a predicted cumulative mortality in intact beak flocks of 3.20% compared with 2.52% in beak trimmed flocks.

(iii) At 70 weeks of age the most common intact beak breed in this dataset, kept in a free range system had a predicted cumulative mortality in intact beak flocks of 8.30% compared with 7.17% in beak trimmed flocks.

Authors' conclusions

Cumulative hen mortality was reduced in beak trimmed flocks kept in free range housing systems (the only housing system for which a sufficient number of beak trimmed and intact beak flocks were available to be analysed). The data indicated that cumulative mortality may be 27% higher in an intact beak flock at 40 weeks of age. This difference was not unexpected given that beak trimming is used as a means to reduce the damage inflicted from injurious pecking, which has been associated with increased mortality.

Values-related components

(i) Most studies on beak trimming, including this one, assume that such interventions are necessary to reduce injurious pecking including feather pecking and cannibalism rather than to attempt to use other solutions such as environmental change first or in lieu of beak trimming.

(ii) This study also used mortality as the sole welfare measure, rather than including other components of welfare including more affective considerations.

Breward, J. & Gentle, M.J. (1985) – Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry.
Experientia 41: 1132

Aim

The authors wanted to investigate the long-term neurological consequences of beak trimming by anatomically and physiologically examining the nerves running to the stump of the beak, in order to identify potential neuroma formation following beak trimming. Neuromas are bundles of nerve cells observed histologically after amputation injury and are believed to be sensitive and potentially painful.

Methods

Twenty Brown Leghorn hens were anaesthetised at 5 weeks of age and beak trimmed using a commercial hot blade beak trimmer. Two birds were euthanased at various intervals after beak trimming (1, 3, 6 and 24 h; and 3, 6, 10, 15, 20, 30 days), and the beaks were removed, and tissue fixed in formalin before subsequent microscopic examination for neuroma formation. For physiological measurements of nerve cell activity, an unspecified number of adult Brown Leghorn hens were anaesthetised, and beak trimmed using a commercial hot blade beak trimmer. At intervals ranging from 1 to 83 days after beak trimming, hens were anesthetised and recordings were made from single afferent fibres of the intramandibular nerve, which carries nerve signals from the lower beak.

Main findings

(i) Following beak trimming, neuromas were observed developing by 15 days after surgery and they were well formed by 20 to 30 days. The prevalence of neuromas is not stated.

(ii) Following partial amputation of the beak, recordings were taken of the electrical activity from single afferent fibres of the intramandibular nerve. A total of 192 single afferent fibre units were isolated, of which 47 were classified as nociceptors, with an abnormal pattern of discharge, and 89 were abnormal spontaneously active units.

Authors' conclusions

The presence of neuromas together with abnormal spontaneous activity originating from them raised serious bird welfare questions concerning beak trimming.

Values-related components

This study relies on anatomical and neurophysiological measures to assess the impacts of beak trimming on welfare without attempting to measure pain or sensitivity, for instance indirectly via behaviours and behavioural change, and hence relies on particular values-related assumptions about appropriate measures and methodologies.

McKeegan, DEF & Philbey, AW. (2012) – Chronic neurophysiological and anatomical changes associated with infrared beak treatment and their implications for laying hen welfare. Animal Welfare 21: 207-217

Aim

The overall aim of this study was to assess the animal welfare impact of the procedure of infra-red beak trimming. The first objective was to characterise the neurophysiological properties of sensory nerve afferents in the beaks of infra-red beak trimmed and control birds at a range of ages representative of commercial laying hens. The second objective was to describe the gross structure and histopathology of the beaks of infra-red beak trimmed and control birds at a range of ages, to examine beak regrowth, regeneration and re-innervation.

Methods

A total of 60 laying hens were obtained from a commercial unit at ages 10, 30 and 50 weeks. Half the birds had been infra-red beak trimmed and the remainder had been left intact. Neurophysiological measurements of anaesthetised birds were used to assess the response to stimulation of a total of 386 nerve fibres of the intramandibular nerve, including mechanoreceptors, thermoreceptors and nociceptors. Gross beak morphology was directly measured as well as through the examination of x-rays. Following euthanasia, histopathological examination was used to look for healing processes and neuroma formation.

Main findings

(i) The entire lower beak was sensitive to thermal and mechanical stimuli, regardless of bird age or beak trimming status.

(ii) There was no evidence of a beak trimming effect on nociceptive thresholds at any age.

(iii) Radiographs produced no evidence of adverse or pathological change in response to infra-red beak trimming.

(iv) Microscopic evaluation of beak-tip anatomy revealed evidence of healing including re-epithelialisation, fibrovascular hyperplasia and bone remodelling. By four weeks of age there was limited nerve regeneration in infra-red beak trimmed beaks, including re-population of mechanoreceptors in some birds.

(v) No neuromas or abnormal proliferations of nerve fibres were observed at any age in response to infra-red beak trimming.

Authors' conclusions

Infra-red beak trimming does not result in chronic pain or other adverse consequences for sensory function.

Values-related components

As with the previous study, this research relies on anatomical and neurophysiological measures to assess the impacts of beak trimming on welfare without attempting to measure pain or sensitivity, for instance indirectly via measurements of behaviours and behavioural change, and hence relies on particular values-related assumptions about appropriate measures and methodologies.

Summary of key literature on beak trimming

Beak trimming and animal welfare

(i) Any examination of the animal welfare implications of beak trimming needs to consider that it is not an issue that occurs in isolation. Beak trimming is a procedure that has been developed to combat the animal welfare and production problems caused by feather pecking and cannibalism. Thus, the first order issue is understanding and, if possible, preventing excessive feather pecking and cannibalism in laying hens (Nicol 2018). Feather pecking and cannibalism are considered in another section of this report.

(ii) Thus, any emphasis on achieving more humane ways of achieving a beak trimmed bird ought not to be at the expense of efforts to prevent the primary problems in the first place. If one accepts that solving feather pecking and cannibalism is likely to be challenging and take some time in commercial operations, then a consideration of ameliorating measures (e.g. beak trimming) and the most humane way to achieve this is appropriate.

(iii) Although not directly examined here, there is some evidence that beak trimming, particularly by hot blade, can adversely affect hen ability to forage and pick up food objects from the ground (e.g. Craig & Lee 1990). This may be due to altered beak morphology, and changes in sensitivity (e.g. through neuroma development).

(iv) These adverse effects are considered to be a greater risk if beak trimming is performed by hot blade, rather than by infra-red at a young age. Hot blade beak trimming is also considered to be a greater risk for producing excessive or uneven beak trims (e.g. Dennis & Cheng 2010a).

Comments on the key papers

(i) The study by Weeks et al. (2016) has the advantage of examining multiple farming operations and flocks, however, the data collection for examining the effects of beak trimming needed to be restricted to free range operations, in order to include sufficient beak trimmed vs. non-trimmed flocks. The design of the study also meant that the sole welfare measure was mortality, which is obviously critically relevant to bird welfare, but which does not always capture the full effect of welfare challenges and benefits.

(ii) The paper by Breward and Gentle (1985) was focused on bird micro-anatomy (through histopathological examination) and on neurophysiology. The impacts on bird welfare are thus inferred due to the changes seen, however, it is not possible to measure pain directly. The study did not include measures of bird behaviour to provide another measurement approach to gauge pain and sensitivity, although other studies have shown the impact of hot blade beak trimming on pecking force (e.g. Dennis & Cheng 2010b), without themselves measuring neuromas.

(iii) The study by McKeegan and Philbey (2012) undertook a comprehensive set of anatomical and physiological tests, and could find no indication of an adverse impact of infra-red beak trimming other than evidence of wound healing and scar tissue formation. From this, the authors concluded that infra-red beak trimming does not result in chronic pain. Again, this conclusion is inferred from the results as it is not possible to measure pain directly, and this particular study did not include behavioural measurements.

6.7 Appendix 7 – Smothering

Barnett J, Rayner AC, Gill R, Willings TH, Bright A (2014) – Smothering in UK free-range flocks. Part 1: incidence, location, timing and management.
Veterinary Record 175, 19-19

Aim

Assessing the incidence, location, timing and management of smothering for the free range laying farms using a questionnaire developed by McDonald's UK Sustainable Egg Supply Group.

Methods

A specific questionnaire was designed addressing three main smothering categories previously described by Bright and Johnson (2011): panic smother, nest box smother and recurring smother. Panic smothering was categorised as smothering triggered by environmental disturbances such as sudden noises or close proximity of a predator, and generally involving large number of birds (> 20 birds). Nest box smothering was categorised as a smothering event that occurs in a nest box when one bird enters the box attracting other birds to enter the same box. A smothering event without an obvious trigger, usually involving a small group of birds (1-10 birds), is categorised as recurring smother. The initial draft of the questionnaire was given to six free range farmers for feedback. Finally, the questionnaire was delivered to farm managers of the two main free range egg supplying companies that represent 35% of the UK free range egg supply.

Main findings

(i) Questionnaires from Company 1 were filled out by farm managers independently, whereas at Company 2 farm managers filled them out in consultation with field managers. The completion rate for the questionnaires was 50% for Company 1 and 100% for Company 2. Farm managers from Company 1 reported panic smother and recurring smother interchangeably, and therefore these two categories were combined for analysis for that particular company.

(ii) **Incidence**: Independent of the number of birds lost in a single smothering event, farm managers were likely to consider smothering as a major welfare concern if they experienced high smothering in previous flocks. Company 1 reported more incidences of nest box smothering compared to panic and recurring, whereas Company 2 reported higher incidences of recurring smother. Overall flock mortality and the number of birds lost during each smother event were higher in panic and recurring smother than in nest box smother.

(iii) **Location**: For both companies, the litter and the corners in the shed and range were the most commonly reported locations for panic and recurring smother events. Company 1 also reported slats and divisions in the shed to be hotspots for panic and recurring smothering to occur. Neither of the companies reported the range to be a key location for smothering events.

(iv) **Time of the day**: Both companies reported the highest percentage of nest box smothering during the morning period. Even so, Company 2 reported the afternoon to be a critical period for panic smother to occur. There was a general consensus at both companies that panic and recurring smother could occur at any time of the day.

(v) **Age of the birds**: There was a general consensus at both the companies that the highest percentage of nest box smothering occurred between 20 and 28 weeks, typically around the

time when hens are in their peak laying cycle. Company 1 reported a high percentage of panic and recurring smother during the entire laying period, whereas Company 2 reported 29-45 weeks as critical period for smothering in the above-mentioned categories to occur.

(vi) **Season*:*** The farm managers in this study did not report any seasonal influence on the smothering events. However, a small number of respondents reported a small spike in the summer months, followed by spring.

(vii) **Management:** Farm managers from both companies who perceived smothering as a welfare issue were significantly likely to implement measures to reduce smothering. Furthermore, irrespective of mortality during a smothering event, farms that experienced a high percentage of smothering in pervious flocks were significantly likely to implement strategies to reduce smothering. Amongst the reduction strategies tried by both companies, blocking off corners, walking birds and reducing noise/stress to the birds were rated as the most effective measures to reduce panic and recurring smother. Company 1 also valued general husbandry as one of the key factors in keeping smothering events in check. Routine checks of nest boxes and blocking nest boxes where recurring smother occurs was reported by farm managers in Company 1 to reduce nest box smother. Company 2 reported changing nest box design to one without shade and perch, and extra walking for birds to be more effective in reducing nest box smother.

Authors' conclusions

This study was the first to provide an overview on the industry estimate of the occurrence of smothering. Based on the results of this study, the authors reported smothering to be a common problem in laying hens, however, due to the unpredictable nature of smothering, currently there are no generalised strategies that can be used to reduce the occurrence at a farm level. The authors acknowledge the retrospective nature of the study, however, they hope that it will provide a basis for future epidemiological studies on smothering.

Values-related components

This study relies heavily on retrospective reporting by farmers, and as such is likely to have embedded a variety of values-related judgements in what data were reported.

Campbell DLM, Makagon MM, Swanson JC, Siegford JM (2016) – Litter use by laying hens in a commercial aviary: dust bathing and piling.
Poultry Science 95, 164-175

Aim

The study examined the spatial use of litter covered open floor in a commercial aviary facility and its effect on hen behaviour and welfare. Of particular interest was the detailed evaluation of piling events, looking at potential causes, piling size, duration and smothering outcomes.

Methods

Two commercial flocks of Lohmann White laying hens reared in aviary system were place in aviary laying sheds between at 17 and 19 weeks respectively. Three units of high-resolution cameras were installed per section, with each camera capturing the outer perch and litter area of eight sections in total. Video recordings were collected at three time points during the laying hens' production cycle, commencing from peak lay period around 24-27 weeks, mid lay period 52-55 weeks, and end lay

period around 76-77 weeks. Piling behaviour in the open litter area was recorded from the time that the aviary was opened until lights off, and a pile was defined as a minimum of 10 hens pressed against each other for at least 1 minute, with their heads facing same direction and not performing any other apparent behaviour. Furthermore, the location of a piling event within the open litter floor, the duration of the event, and the total number of hens involved in the event were also recorded.

Main findings

(i) **Incidence**: During the entire data collection period a total of 66 piling events were observed in Flock 1, and 108 in Flock 2. Each section, amongst the all of the sample collection points, at least had 1 piling event.

(ii) **Location**: The highest number of piles in Flock 1 was seen by the gate, whereas in Flock 2 the highest number of piling events occurred against the wall. A very small proportion of piling events started from the gate and moved to the wall.

(iii) **Timing**: Piling events occurred throughout the day from the time that hens had access to litter, for all of the recording time points for both the flocks. The range of duration of the piling events, across both of the flocks ranged from 1 minute to 359 minutes. The longest lasting piling event was seen in the afternoon. Flock 2 had more long-lasting events (> 1 hour) than Flock 1. For Flock 2, piling events that occurred during the mid-lay period were the longest, and those seen during peak lay were the shortest.

(iv) Overall, piling events were always localised and never included all hens in a section. The piles within each event were dynamic throughout their duration, with hens constantly leaving and joining the piles. The authors' personal observation was that some hens were motivated to get to the centre of the pile and would walk over the top of other hens to squeeze themselves into the middle.

Authors' conclusions

Even though no deaths occurred during the piling events in this study, it is an important study that reports on the nature of piling within aviaries in the US. Piling observed in this study was similar to recurring smother described by Bright and Johnson (2011). The authors could not conclude whether piling events such as the ones seen in this study represented welfare concerns as they were not followed by smothering.

Values-related components

(i) As with the above study, this study relies heavily on retrospective reporting by farmers, and as such is likely to have embedded a variety of values-related judgements in what data were reported.

(ii) This study holds that mortality via smothering is the main indicator of welfare concerns and does not use a more expanded definition of what constitutes 'welfare'.

De Haas EN, Kemp B, Bolhuis JE, Groothuis T, Rodenburg TB (2013) – Fear, stress and feather pecking in commercial white and brown laying hen parent-stock flocks and their relationships with production parameters.
Poultry science 92, 2259-2269

Aim

Assessing the relationship between fear responses, physiological measurements, feather damage, and productivity in commercial parent stock flocks originating from White Leghorn and Rhode Island Red strains.

Methods

Ten ISA (originating from Rhode Island white hens and Rhode Island red rooster) parent stock flocks and 10 DW (originating from White Leghorn hens and roosters) parent stock flocks used for the study from 20 to 65 weeks of age. The flocks were housed in a commercial farm, using floor housing with partly slatted floors. To address the main aims of the study a wide range of production parameters was recorded, specifically, cumulative mortality levels were recorded at the beginning and end of the data collection period. The study also recorded the occurrences of smothering events that led to mortality of a large number of birds at specific time points. The farmer's records were used to establish the overall incidence of smothering within each flock.

Main findings

(i) ISA flocks had a higher incidence of smothering than DW flocks ($X_2 = 13.1$, $p = 0.003$). Overall, smothering was higher in small flocks compared to flocks with a larger group size ($X_2 = 5.3$, $p = 0.02$).

(ii) Nest box smothering was noticed mainly during onset and peak of production cycle in laying hens, irrespective of the genotype (complete data not shown).

(iii) DW birds had 13% lower body weight than ISA birds, and since the stocking densities for both strains were the same, ISA birds might be constrained, which in turn might increase the risk of smothering in this strain of hens.

(iv) The high mortality seen in ISA flocks was attributed to smothering events.

Authors' conclusions

The ISA strain of birds showed increased fear of humans and were more at risk of smothering events, especially in smaller flocks. The authors believe social adherence either due to fearful events or other causes might be the reason ISA birds in small flocks were more susceptible to smothering. In order to improve the welfare of parent stock, better management practices with specific focus on human-animal relationship should be implemented.

Values-related components

As with the above studies, this study relies heavily on retrospective reporting by the farmer, and as such is likely to have embedded a variety of values-related judgements in what data were reported.

Summary of key literature on smothering

Comments on the key papers

(i) The study by Barrett et al. (2014) is the first to provide valuable information on the incidence, location, timing and management of smothering in commercial laying hen farms. As the participating companies made up 35% of the UK free range supply, the findings of this study may give us a realistic industry estimate for smothering in UK. The questionnaire used by the authors was designed in consultation with free range farm managers and hence can be relied upon to be in-depth. Importantly, the study highlights the unpredictable nature of smothering events, for which reason a singular mitigation approach cannot be employed. One of the biggest drawbacks of a retrospective study such as this one is that a huge emphasis is placed on farmers' records, and hence there is always a risk of getting incomplete or inaccurate information. Nonetheless, this study has been vital in highlighting some crucial aspects of smothering and paving the way for more systematic studies on the topic.

(ii) With an increasing number of commercial laying hens now being housed in aviaries, the study by Campbell et al. (2016) is important in increasing our understanding of hen behaviour in such housing systems. Although none of the piling recorded in this study led to smothering events, the study highlights the hotspots for such events within an aviary system. The results of this study are very similar to those found by Barnett et al. (2014), however, unlike the latter, the current study was unable to explain the cause for any of the piling events. Results from this study demonstrate differences in the nature of piling events between aviary and free range housing systems (Barrett et al. 2014, Bright & Johnson 2011).

(iii) The study by De Haas et al. (2013), although not solely focused on smothering, highlights the effect of genotype on smothering incidences. One of the unique aspects of this study was that it looked at the welfare of parent stock, which originated from different genotypes, and which has remained largely uninvestigated. Even though smothering was only a small proportion of this large-scale study, they were able to report important associations between genotype and smothering, and to conclude that the highest mortality rates as seen in ISA strain of birds was due to smothering. As with most smothering studies so far, one of the main limiting factors of this study is its reliance on farmers' records.

6.8 Appendix 8 – Antibiotic use

van den Bogaard, AE, London, N, Driessen, C and Stobberingh EE. (2001) – Antibiotic resistance of faecal Escherichia coli in poultry, poultry farmers and poultry slaughterers.
Journal of Antimicrobial Chemotherapy 47: 763-771

Aim

The aim of this paper was to determine the prevalence of antibiotic-resistant strains of faecal *E. coli* bacteria in laying hens, broiler birds and turkeys, as well as the prevalence in the farmers who operated these enterprises and the slaughterhouse workers where the birds were processed.

Methods

The percentage of faecal samples containing resistant *Escherichia coli* and the proportion of resistant faecal *E. coli* were determined in three poultry populations: broilers and turkeys commonly given antibiotics, and laying hens treated with antibiotics relatively infrequently. Faecal samples of five human populations were also examined: turkey farmers, broiler farmers, laying-hen farmers, broiler slaughterers and turkey slaughterers.

Main findings

(i) The proportion of faecal samples containing resistant *E. coli* and the percentages of resistant *E. coli* were significantly higher in turkeys and broilers than in the laying hen population.

(ii) Resistance to nearly all antibiotics in faecal *E. coli* of turkey and broiler farmers, and of turkey and broiler slaughterers, was higher than in laying-hen farmers.

(iii) Multi-resistant *E. coli* isolates were common in turkey and broiler farmers but absent in laying-hen farmers. The same resistance patterns were found in turkeys, turkey farmers and turkey slaughterers and in broiler, broiler farmers and broiler slaughterers.

(iv) The genotype patterns of the *E. coli* isolates from the eight human populations were quite variable, but *E. coli* with an identical genotype pattern were isolated at two farms from a turkey and the farmer, and also from a broiler and a broiler farmer from different farms. Moreover, three *E. coli* isolates from turkey meat were identical to faecal isolates from turkeys.

Authors' conclusions

The results of this study strongly indicate that transmission of resistant clones and resistance plasmids of *E. coli* from poultry to humans commonly occurs.

Values-related components

The study assumes that antibiotic use is a necessary part of livestock farming.

Summary of key literature on antibiotic use

Antibiotic use and animal welfare

(i) Mass administration of antimicrobials in intensive animal production is undertaken to: (a) treat an existing disease condition (therapeutic use); (b) prevent a potential disease (prophylactic use); or (c) promote animal growth rates through modification of gastro-intestinal bacterial populations (growth promotant use).

(ii) Although modern concepts of antimicrobial stewardship are aimed at slowing the development of multi-drug resistant bacterial strains through avoiding excessive antibiotic use, if animals are suffering from a treatable bacterial disease then antibiotic treatment may be in the best interests of their welfare. The longer-term goal of antimicrobial stewardship is to reduce the prevalence of infections through measures such as hygiene, biosecurity and vaccination.

(iii) Routine mass medication with antimicrobials for prophylactic use is now considered problematic, increasing the rate at which bacteria develop resistance. Prophylactic use of antimicrobials should not be considered as a substitute for good hygiene and other disease prevention measures.

(iv) Antibiotics are thought to be able to exert a growth promotant effect through improving the efficiency of animal growth by inhibiting normal microbiota, leading to increased nutrient utilisation and a reduction in maintenance costs of the gastrointestinal system. Although the antimicrobial agents used as growth promotants in animal production are typically different in class and mode of action to those used therapeutically in human medicine, restrictions and bans on their use are gradually coming into force (Castanon 2007).

(v) In the long term, any reduced availability of antimicrobials for treating poultry that arises through multi-drug resistance or through regulatory restrictions will adversely affect bird welfare.

Comments on the key paper

(i) The results of the study by (Van den Bogaard et al. 2001) at first glance appear favourable for the laying hen sector because of the much lower prevalence of resistant *E. coli* compared with the broiler and turkey sectors.

(ii) However, the clear relationships shown between resistant bacterial strains in farmed broilers and turkeys, and associated humans, support the drive for higher levels of antimicrobial stewardship, which in turn may place limitations on antibiotic availability for laying hens.

6.9 Appendix 9 – Management and stockmanship

Barnett JL, Hemsworth PH, Newman EA (1992) – Fear of humans and its relationships with productivity in laying hens at commercial farms.
British Poultry Science 33, 699-710

Aim

The aim was to examine the relationship between fear of humans and productivity of laying hens in commercial environments, as previously found experimentally by Hemsworth and Barnett (1989).

Methods

(i) The relationship between the behavioural responses of caged laying hens to humans and productivity was determined at 16 commercial flocks in Australia. The 16 commercial flocks were housed in sheds of two types of construction (seven fully enclosed sheds and nine partially enclosed sheds) and had two arrangements of cages (six with a single tier and 10 with two or more tiers). Hens were observed during one day in each shed at between 40 and 54 weeks of age, having been in the shed for a minimum of 21 weeks.

(ii) To assess fear of humans, two behavioural tests were conducted at between 40 and 52 weeks of age to assess the behavioural response of individual hens to an approaching experimenter in a novel arena ('Shute test') and the behavioural response of caged hens to an experimenter approaching the cage ('Approaching human test'). Measurements taken in both tests included the position, orientation and posture of the hens to the approach of the experimenter. In addition, a third test was conducted to assess the behavioural response of caged hens to a novel object placed in the hens' cages ('Novel object test') and the position, orientation and posture of the hens were recorded.

(iii) In all tests, hens were selected so that all tiers and aisles, and several positions in each aisle were sampled to give a representative sample of the whole flock. In sheds containing cages with more than one hen, the hen to be tested was selected using a random number sheet, as the experimenter walked down the aisle to approach the cage (hens numbered 1 to 4 on the basis of proximity to the approaching experimenter). No hen was used in more than one test and in each row the test cages were a minimum of 6 cages apart between consecutive tests. The order of rows, tiers and starting end for each row was pseudo-randomised so that hens were tested in sequence along a row.

(iv) The producers provided records of egg production and mortalities (including culls). The mortality figures were corrected for strain using figures from a random sample layer test (Mason et al. 1988). The production and mortality data were corrected to that of Tegel Tint hens (the strains used in the study were Tegel Tint, Tegel Super Tint, Tegel Brown, Hy-Line No. 1, Hy-Line No. 2, Hy-Line No. 3 and SIRO CB; these strains were derived from White Leghorn, New Hampshire and Australorp breeds).

(v) Correlation and step-wise multiple regression analyses were used to examine relationships between the farm factors, behavioural and production variables in the 16 sheds. For the multiple regression analyses, all statistically significant variables from the correlation matrix were used, and the minimisation procedure dropped variables progressively from the analysis until the maximum variation was accounted for.

Main findings

(i) A number of variables measured in the behavioural tests were moderately to highly correlated with production variables. For example, the proportion of birds that moved away from and oriented towards the approaching experimenter in an unfamiliar environment (Shute test) were negatively correlated with peak hen day production and hen mortality.

(ii) The step-wise multiple regression analyses indicated that the behavioural response to the experimenter in the Shute test and the Approaching human test accounted for between 23 and 63% of the variation in a number of production variables, including peak hen day production, the duration of a high level of production and hen mortality (examples presented in Table 6). Inclusion of farm factor variables increased the amount of variation accounted for by the behaviour variables. For example, adding the variable 'time/day spent in the shed by stockpeople' to the behaviour variables 'the proportion of birds that moved away from an approaching human' in the Shute test and 'the number of times birds in cages adopted an erect posture' in response to an approaching human increased the variation accounted for in peak hen day production from 53 to 61%.

Table 6 Proportion of variance accounted for ([adjusted]R^2) and level of significance (from the analysis of variance) from the stepwise multiple regression analyses, with production as the dependent variable and bird behaviour as the independent variable

Dependent variable	Independent variable	R^2	Probability
Peak hen day production	Withdrew in Shute test Erect in Approaching human test	0.53	$P < 0.01$
Head day production (26-54 weeks)	Withdrew in Shute test	0.28	$P < 0.05$
Mortality (26-44 weeks)	Orient forward in Novel object test Erect in Approaching human test	0.33	$P < 0.05$

Authors' conclusions

The results suggest that fear of humans may be a factor that limits the productivity of commercial laying hens. While the associations found here between behaviour and production do not show a cause and effect relationship, their presence, in spite of the heterogeneity in shed design, cage size, strain of bird and a number of farm factors, suggests they are robust. Further research is clearly warranted to determine the factors that regulate the behavioural responses, so that these factors can be manipulated to examine the consequences on productivity.

Values-related components

The study only utilised caged housing in its evaluations of the effects of fear of humans on hen behaviour, rather than including alternative housing environments.

Hemsworth PH, Coleman GJ (2009) – Animal welfare and management.
Food Safety Assurance and Veterinary Public Health, Volume 5 – Welfare of Production Animals: Assessment and Management Risks, edited by F.J.M. Smulders and B. Algers
Wageningen Academic Publishers, The Netherlands, pp. 133-147

Aim

This book chapter considers how farm animal management affects farm animal welfare.

Methods

This chapter reviews how:

(i) **at the level of the stockperson**, the three main classes of stockperson characteristics, stockperson capacity, stockperson willingness and stockperson opportunity, contribute to animal welfare.

(ii) **at the farm level**, how farm management practices, including employee selection and training, can affect these stockperson characteristics.

An understanding of the impact of these stockperson characteristics and how farm management practices can affect them, can be utilised to develop strategies to improve stockperson performance as well as monitoring stockperson performance.

Main findings

(i) **What has been achieved?** While the welfare of farm animals is affected by a diverse range of factors such as their physical and social environment and their nutrition and health status, there is considerable research that shows that management practices at the farm level and at the level of the stockperson play a pivotal role in determining the welfare of farm animals.

Stockpeople have direct effects on animal welfare, via their behaviour towards animals, their husbandry skills and knowledge, and their motivation to apply these skills and knowledge. The capacity and willingness of stockpeople to supervise and manage farm animals are important attributes determining animal welfare, since these factors influence the likelihood of best practice by stockpeople in terms of their handling behaviour, their husbandry skills, their technical knowledge and their willingness to implement these. Furthermore, the human resource management practices of the farm, including employee selection and training, management style and organisational policies and rules that affect working conditions, can affect these important attributes of stockpeople.

(ii) **What has been neglected?** The role of the stockperson in determining animal welfare has generally been neglected in the animal farming industries. Recent research has shown that the role and impact of the stockperson on the animal should not be underestimated and that to do so will seriously risk the welfare and productivity of livestock. It is likely that in the near future both the livestock industries and the general community will place an increasing emphasis on ensuring the competency of stockpeople that manage livestock. In the future, welfare audits will necessarily include stockmanship.

Authors' conclusions

(i) **What needs to be done?** Farm management approaches that maximise stockperson performance are an essential part of farm animal production, and there is limited relevant research in agriculture and little evidence of systematic utilisation of these approaches.

Therefore, an understanding of these influential characteristics of stockpeople that affect farm animal welfare and the effects of local factors, such as management style and working conditions, on these influential stockperson characteristics is important in developing human resource and organisational policies to ensure that the stockperson is equipped to effectively care for and manage farm animals. Such policies would include employee selection and training targeting these influential stockperson characteristics, as well as a working environment that reduces employee levels of stress, enhances a positive group culture to the animal and animal management tasks, and provides jobs that offer skill variety, task significance, autonomy and feedback. Welfare audits that include stockperson performance will provide a mechanism for delivering feedback to stockpeople, management and the wider community.

Values-related components

As this is a review book chapter, rather than an experimental study, it does not have values-based elements of itself, although the individual studies included in the chapter would have values-related components.

Edwards LE (2009) – The human-animal relationship in the caged laying hen.
PhD thesis, University of Melbourne, Victoria, Australia

Aim

The aim of this study was to determine whether a sequential relationship exists between stockperson attitudes, stockperson behaviour, fear of humans in laying hens and hen productivity on commercial farms in Australia and the US.

Methods

(i) The relationship between the behavioural responses of caged laying hens to humans and productivity was studied in 20 Australian flocks and 9 US flocks. The strain of hens, group and cage size, and shed design varied between flocks.

(ii) Data were collected on each flock over a three-day period. Behavioural tests were administered to the birds on the first day, as well as collection of egg samples for subsequent assessment of albumen corticosterone concentrations, and observations on stockperson behaviour in the sheds were conducted on the following two days. At the end of the three-day period, an attitude questionnaire was administered to the main stockpeople observed in each shed. While the aim was to study hens between 38 and 60 weeks of age, several farms were unable to be visited while the birds were at this age due to time constraints particularly in the US sheds, and thus the ages ranged between 28 and 105 weeks of age. Where possible the productivity records for the entire laying life of the flock were obtained.

(iii) Fear of humans in hens was assessed on Day 1 using two behavioural tests in which the experimenter observed the avoidance response of hens while walking slowly along the corridors and the avoidance response to close and repeated approaches to individual cages.

(iv) Due to difficulties in importing frozen faecal samples to Australia, only the Australian egg samples were assayed but because of the small sample size, these data are not presented here.

(v) Stockperson behaviour was observed for two days in each shed. The researcher recorded the frequency of a range of behaviours displayed by the stockpeople using a bout criterion interval of 5 seconds for each behaviour. The time that the stockpeople spent in the sheds and their speed of movement were also recorded.

(vi) The attitude questionnaire, which was developed using focus groups, consisted of questions designed to assess the attitudes of the stockpeople towards hens and working with them; beliefs about other people's expectations of them (normative beliefs); and their beliefs about the extent to which they have control over how they interact with and manage their birds (control beliefs).

(vii) Due to the significant differences between countries described above, partial correlation analyses were conducted with country partialled out to determine relationships between stockperson attitudes, stockperson behaviour, hen behaviour and productivity. Stepwise linear regression analyses were conducted to further explore these relationships.

Main findings

(i) **Stockperson attitudes and behaviour.** The attitudes and empathy of stockpeople were associated with their behaviour. In general, negative stockperson attitudes were associated with more noise, faster speed of movement, more time in the shed, less time spent stationary, less time at the start of the shed and less time in the ends of the aisles. The relevant negative attitudes include the insensitivity of the stockperson to the responsiveness of the hens, finding the work unpleasant, and having negative general beliefs about hens. Positive attitudes and empathy were associated with less noise and less time spent in the shed. These positive attitudes include the sensitivity of the stockperson to the responsiveness of the birds and having positive general beliefs about hens.

(ii) **Human behaviour and hen fear and productivity.** Fear of humans in caged laying hens, based on their avoidance response to a researcher in two tests, was lower in flocks in which the stockpeople made less noise, moved slower, made more close approaches to cages, displayed more behaviours close to cages and spent more time in the aisles adjacent to the cages.

(iii) Peak egg production was predicted to be greater in sheds where the stockpeople made more noise but moved more slowly. The number of weeks that the birds sustained egg production within 5% of their peak was predicted to be greater when there was more noise occurring in the shed. However, noise made by the stockperson, which was often associated with cleaning the shed, was positively correlated with both fear and egg production.

Authors' conclusions

While the relationships between stockperson attitudes, stockperson behaviour and hen fear support the literature on human-animal relationships in other livestock industries (Hemsworth & Coleman 2011), the relationships between stockperson noise and hen productivity cannot be explained, however, it may be related to the management style and cleanliness of the laying sheds. That is, noise made by the stockperson was often associated with cleaning the shed, and thus these findings suggest that the benefits of hygienic conditions may outweigh the negative impacts of hen fear on egg production.

Values-related components

The study only utilised caged housing in its evaluations of the effects of fear of humans on hen behaviour, rather than including alternative housing environments.

Waiblinger S, Zaludik K, Raubek J, Gruber B, Niebuhr K, (2018) – Human-hen relationship on grower and laying hen farms in Austria and associations with hen welfare.
Proceedings of the 52nd Congress of the International Society for Applied Ethology
Charlottetown, Prince Edward Island, Canada, pg. 187 (abstract)

Aim

The aim of this study was to investigate, the variability in farmers' attitudes, handling practices, the hen-human relationship and their associations, as well as with measures of welfare.

Methods

Fifty non-cage layer flocks (30-40 weeks of age) were visited once. The hens' relationship towards humans was assessed by measuring their reactions to humans in standardised, validated tests (avoidance response to the approaching experimenter and tactile contact by the stationary experimenter). Information on work organisation, handling practices and attitudes of the main stockperson were collected by a questionnaire, and farm/flock characteristics and management practices via a pre-structured interview. Plumage condition, skin injuries and housing characteristics were evaluated directly, and mortality from farm records. Attitude factors were derived from principal component analysis on single items. Correlation analysis and non-parametric tests (Mann-Whitney U test) were used to examine relationships between the attitudes, stockperson behaviour, and hen fear of humans, feather condition and morality.

Main findings

Working routines, stockperson contact with hens and handling practices correlated with attitudes, hen fear and welfare. For example:

(i) Stockpeople at layer flocks that reported that they caught their hens regularly ranked higher in their beliefs about the importance of regular contact, intensive care and housing on hen welfare (Mann-Whitney U, P = 0.045), and in these flocks more hens could be touched by the stationary experimenter (P = 0.010) and more hens showed no avoidance to the approaching experimenter (P = 0.033).

(ii) The percentage of hens with feather damage correlated positively with the median avoidance of hens to the approaching experimenter (r_s = 0.43, P = 0.002) and negatively with the number of hens that could touched (r_s = -0.31, P = 0.028) and with beliefs about the importance of contact with hens on hen welfare (r_s = -0.43, P = 0.040).

(iii) Negative general attitude correlated positively to the percentage of hens with feather damage (r_s = 0.37, P = 0.008) and mortality (r_s = 0.31, P = 0.047).

Authors' conclusions

Under commercial free range conditions, Waiblinger et al. (2018) found significant relationships between stockperson attitudes, their subsequent interactions with the laying hens, and the feather damage and mortality rates of those hens. The results confirm sequential relationships found in other

farm animal species, and suggest that human attitudes and subsequent behaviour are important for an improved hen-human relationship and hen welfare in non-caged hens.

Values-related components

Although the findings are largely correlational, there is an inherent assumption of causation in how these results are typically interpreted.

Summary of key literature on management and stockmanship

Human-farm animal relationship

(i) The three key papers considered here, Barnett et al. (1992), Edwards (2009) and Waiblinger et al. (2018), assessed fear of humans in laying hens by measuring the avoidance response of laying hens to an approaching experimenter or the lack of avoidance of laying hens to a stationary experimenter. These behavioural tests or adaptations of them have been shown to be valid tests of fear (Graml et al. 2008).

(ii) The most studied aspect of the human-farm animal relationship from the perspective of the farm animal has been fear responses to humans, both behavioural and physiological. Fear, as with other affective experiences, cannot be measured or observed directly, but can be inferred from the behaviour and stress physiology of the animal (see review by Hemsworth et al. (2018)). As reviewed by Waiblinger et al. (2006), tests measuring the animals' behavioural responses to humans can be categorised into three main types: (a) responses to a stationary human; (b) responses to an approaching human; and (c) responses to actual handling.

(iii) Fear is not the only affective experience that has been assessed and that may influence the animal's response to humans. Animals may experience positive or pleasant affective experiences in the presence of humans that may arise from associating humans with rewarding events. Through conditioning, animals associate humans with rewarding events such as feeding, and show increased attraction to humans on the basis of approach behaviour (see review by Hemsworth et al. 2018).

(iv) Inter-individual relationships are based on the history of regular interactions between two individuals, and (Estep 1992) argued that human-animal relationships could be viewed in a similar manner and that studies of this relationship should be undertaken by investigating each partner's perception of the relationship. Each individual partner's perception of the relationship allows it to interpret and predict future interactions. Therefore, if animals are able to learn and anticipate future interactions, the concept of the relationship exists not only for each partner of the relationship but also for an external observer, and consequently the quality of the relationship for the partners can be studied. Waiblinger et al. (2006) proposed that different affective experiences and motivations are involved in the animal's perception of and reaction to humans, and that these are likely to determine the strength of an animal's relationship with humans, which may therefore vary from negative through neutral to positive.

Comments on the key papers

(i) In comparison to dairy and pigs, there is limited research on the characteristics of stockpeople that influence the welfare of the laying hens. Nevertheless, the three key papers considered here, Barnett et al. (1992), Edwards (2009) and Waiblinger et al. (2018), demonstrate relationships in field studies between stockperson characteristics, hen fear and hen welfare

and support the evidence in the literature that understanding stockperson-farm animal relationships have implications for improving farm animal welfare. While the significant relationships found in these studies suggest the possibility of causality, observational and correlational studies like these three studies make causality difficult, if not impossible, to determine. However, these results provide a rationale for experimental research in which stockperson variables are manipulated in a controlled manner to determine causality.

(ii) Intervention studies conducted in the dairy (Hemsworth et al. 2002) and pig industries (Coleman et al. 2000, Hemsworth et al. 1994), targeting the key attitudes and behaviour of stockpeople that were previously found to be correlated with fear responses of cows and pigs to humans resulted in reductions in these fear responses. Furthermore, concurrent improvements in animal productivity were observed: there were improvements in the milk yield of dairy cows and a marked tendency for an improvement in the reproductive performance of sows. These studies demonstrated that stockperson attitudes are amenable to change, and that stockperson training can improve human-animal relationships and in turn animal welfare in these livestock industries. Research and development on similar opportunities in the egg industry are lacking.

(iii) The other key paper considered here, the review paper by Hemsworth and Coleman (2009), while recognising the importance of stockperson attitudes and behaviour on animal welfare, also recognises the importance of other stockperson characteristics such as husbandry skills and knowledge, and the motivation to apply these skills and knowledge. Furthermore, the authors acknowledge that at the farm level, animal management practices, such as best practice in housing and husbandry, and implementation of welfare protocols and audits, all impact on farm animal welfare. It is also relevant that the authors report that improved human-animal interactions may also enhance job-related characteristics, such as job satisfaction, motivation, and commitment, thereby potentially improving the stockperson's job performance and career prospects (Coleman & Hemsworth 2014).

(iv) Therefore, while there are limited data for laying hens, these results and other papers on other farm animal species highlight the pivotal role of humans on farm animal welfare, and highlight opportunities to improve human-farm animal interactions and thus human-farm animal relationships.

7 References

1. Aerni, V., H. El-Lethey and B. Wechsler (2000). Effect of foraging material and food form on feather pecking in laying hens. *British poultry science* 41(1) 16-21.
2. Barnett, J., P. Hemsworth and E. Newman (1992). Fear of humans and its relationships with productivity in laying hens at commercial farms. *British poultry science* 33(4) 699-710.
3. Barnett, J. L., et al. (2001). A review of the welfare issues for sows and piglets in relation to housing. *Australian journal of agricultural research* 52(1) 1-28.
4. Barrett, J., et al. (2014). Smothering in UK free-range flocks. Part 1: incidence, location, timing and management. *Veterinary record* 175(1) 19-19.
5. Baxter, M. (1994). The welfare problems of laying hens in battery cages. *The Veterinary Record* 134(24) 614-619.
6. Bearse, G., et al. (1949). The effect of pelleting chicken rations on the incidence of cannibalism. Poultry Science, POULTRY SCIENCE ASSOC INC 1111 NORTH DUNLAP AVE, SAVOY, IL 61874.
7. Beuving, G. and G. Vonder (1978). Effect of stressing factors on corticosterone levels in the plasma of laying hens. *General and Comparative Endocrinology* 35(2) 153-159.
8. Blokhuis, H. (1986). Feather-pecking in poultry: its relation with ground-pecking. *Applied Animal Behaviour Science* 16(1) 63-67.
9. Breuner, C. W., B. Delehanty and R. Boonstra (2013). Evaluating stress in natural populations of vertebrates: total CORT is not good enough. *Functional Ecology* 27(1) 24-36.
10. Breward, J. and M. Gentle (1985). Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry. *Experientia* 41(9) 1132-1134.
11. Bright, A. and E. Johnson (2011). Smothering in commercial free-range laying hens: a preliminary investigation. *Veterinary record* 168(19) 512-512.
12. Broom, D. and M. Corke (2002). Effects of disease on farm animal welfare. *Acta Veterinaria Brno* 71(1) 133-136.
13. Campbell, D., et al. (2016). Litter use by laying hens in a commercial aviary: dust bathing and piling. *Poultry Science* 95(1) 164-175.
14. Castanon, J. (2007). History of the use of antibiotic as growth promoters in European poultry feeds. *Poultry Science* 86(11) 2466-2471.
15. CEC (1999). Council Directive 99/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. *Official journal of the European Communities* 53-57.
16. Coleman, G. and P. Hemsworth (2014). Training to improve stockperson beliefs and behaviour towards livestock enhances welfare and productivity. *Rev. Sci. Tech* 33 131-137.
17. Coleman, G., et al. (2000). Modifying stockperson attitudes and behaviour towards pigs at a large commercial farm. *Applied Animal Behaviour Science* 66(1-2) 11-20.
18. Cook, C., et al. (2000). Hands-on and hands-off measurement of stress. *The biology of animal stress: basic principles and implications for animal welfare. CABI Publishing, Wallingford, UK* 123-146.

19. Cooper, J. and M. C. Appleby (1997). Motivational aspects of individual variation in response to nestboxes by laying hens. *Animal Behaviour* 54(5) 1245-1253.

20. Cooper, J. J. and M. C. Appleby (1996). Demand for nest boxes in laying hens. *Behavioural Processes* 36(2) 171-182.

21. Craig, J. and H.-Y. Lee (1990). Beak trimming and genetic stock effects on behavior and mortality from cannibalism in White Leghorn-type pullets. *Applied Animal Behaviour Science* 25(1-2) 107-123.

22. Dawkins, M. S. (1990). From an animal's point of view: motivation, fitness, and animal welfare. *Behavioral and brain sciences* 13(1) 1-9.

23. Dawkins, M. S. (2003). Behaviour as a tool in the assessment of animal welfare. *Zoology* 106(4) 383-387.

24. Dawkins, M. S. (2008). The science of animal suffering. *Ethology* 114(10) 937-945.

25. De Haas, E., et al. (2013). Fear, stress, and feather pecking in commercial white and brown laying hen parent-stock flocks and their relationships with production parameters. *Poultry Science* 92(9) 2259-2269.

26. Dennis, R. L. and H. W. Cheng (2010a). A comparison of infrared and hot blade beak trimming in laying hens. *International Journal of Poultry Science* 9(8) 716-719.

27. Dennis, R. L. and H. W. Cheng (2010b). Effects of beak trimming on pecking force. *Int. J. Poult. Sci* 9 863-866.

28. Duncan, I. J. and D. Fraser (1997). *Understanding animal welfare*.

29. Edwards, L. (2009). The human-animal relationship in the caged laying hen. *Animal welfare science centre*. University of Melbourne.

30. El-Lethey, H., et al. (2000). Stress and feather pecking in laying hens in relation to housing conditions. *British poultry science* 41(1) 22-28.

31. Elliott, K. C. (2017a). *A tapestry of values: an introduction to values in science*: Oxford University Press.

32. Elliott, K. C. (2017b). Rather than being free of values, good science is transparent about them. *The Conversation*. https://theconversation.com/rather-than-being-free-of-values-good-science-is-transparent-about-them-84946.

33. Engel, J., et al. (2018). The effects of floor space and nest box access on the physiology and behavior of caged laying hens. *Poultry Science*.

34. Estep, D. Q. (1992). Interactions, relationships and bonds: the conceptual basis for scientist-animal relation. *The Invitable Bond: Examing Scientist-Animal Interactions* 6-26.

35. FAWC (1997). Report on the welfare of laying hens. https://webarchive.nationalarchives.gov.uk/20110909181249/http://www.fawc.org.uk/reports/layhens/lhgretoc.htm

36. Fleming, R., et al. (2004). Incidence, pathology and prevention of keel bone deformities in the laying hen. *British poultry science* 45(3) 320-330.

37. Fleming, R., et al. (2006). Relationships between genetic, environmental and nutritional factors influencing osteoporosis in laying hens. *British poultry science* 47(6) 742-755.

38. Follensbee, M., I. Duncan and T. Widowski (1992). Quantifying nesting motivation in domestic hens. *Journal of Animal Science* 70 164.

39. Fossum, O., et al. (2009). Causes of mortality in laying hens in different housing systems in 2001 to 2004. *Acta Veterinaria Scandinavica* 51(1) 3.

40. Fraser, D. (2003). Assessing animal welfare at the farm and group level: the interplay of science and values.

41. Freire, R., A. M. C and B. O. Hughes (1997). Assessment of pre-laying motivation in the domestic hen using social interaction. *Animal Behaviour* 54(2) 313-319.

42. Freire, R. and A. Cowling (2013). The welfare of laying hens in conventional cages and alternative systems: first steps towards a quantitative comparison. *Animal welfare* 22(1) 57-65.

43. Graml, C., S. Waiblinger and K. Niebuhr (2008). Validation of tests for on-farm assessment of the hen–human relationship in non-cage systems. *Applied Animal Behaviour Science* 111(3-4) 301-310.

44. Green, L., et al. (2000). Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary record* 147(9) 233-238.

45. Gross, W. and H. Siegel (1983). Evaluation of the heterophil/lymphocyte ratio as a measure of stress in chickens. *Avian diseases* 972-979.

46. Hemsworth, P. (2018). Key determinants of pig welfare: implications of animal management and housing design on livestock welfare. *Animal production science* 58(8) 1375-1386.

47. Hemsworth, P. and G. Coleman (2009). Animal welfare and management. *In* F. Smulders and B. Algers eds. *Food safety assurance and veterinary public health*. Wageningen Academic Publishers, The Netherlands. 133-147.

48. Hemsworth, P., G. Coleman and J. Barnett (1994). Improving the attitude and behaviour of stockpersons towards pigs and the consequences on the behaviour and reproductive performance of commercial pigs. *Applied Animal Behaviour Science* 39(3-4) 349-362.

49. Hemsworth, P., et al. (2002). The effects of cognitive behavioral intervention on the attitude and behavior of stockpersons and the behavior and productivity of commercial dairy cows. *Journal of Animal Science* 80(1) 68-78.

50. Hemsworth, P., S. Sherwen and G. Coleman (2018). Human contact. *In* M. Appleby, I. Olsson and F. Galindo eds. *Animal welfare*. Oxon UK. 294-314.

51. Huber-Eicher, B. and B. Wechsler (1997). Feather pecking in domestic chicks: its relation to dustbathing and foraging. *Animal Behaviour* 54(4) 757-768.

52. Hughes, B. and I. Duncan (1972). The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British poultry science* 13(6) 525-547.

53. Hughes, B., I. Duncan and M. F. Brown (1989). The performance of nest building by domestic hens: is it more important than the construction of a nest? *Animal Behaviour* 37 210-214.

54. Koelkebeck, K., M. Amoss Jr and J. Cain (1987). Production, physiological, and behavioral responses of laying hens in different management environments. *Poultry Science* 66(3) 397-407.

55. Koolhaas, J. M., et al. (2011). Stress revisited: a critical evaluation of the stress concept. *Neuroscience & Biobehavioral Reviews* 35(5) 1291-1301.

56. Lambton, S., et al. (2013). A bespoke management package can reduce levels of injurious pecking in loose-housed laying hen flocks. *Veterinary record* 172(16) 423-423.

57. Lambton, S. L., et al. (2010). The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens. *Applied Animal Behaviour Science* 123(1-2) 32-42.

58. Lay, D., et al. (2011). Hen welfare in different housing systems. *Poultry Science* 90(1) 278-294.

59. Mason, G. (1998). A demanding task: using economic techniques to asess animal priorities. *Anim. Behav.* 55 1071-1075.

60. Mason, G. J. and C. C. Burn (2011). Behavioural restriction. *Animal welfare* 98-119.

61. Mason, G. J., J. Cooper and C. Clarebrough (2001). Frustrations of fur-farmed mink. *Nature* 410(6824) 35.

62. Mason, J. W. (1968). A review of psychoendocrine research on the pituitary-adrenal cortical system. *Psychosomatic medicine* 30(5) 576-607.

63. Mason, J. W. (1975). A historical view of the stress field. *Journal of human stress* 1(2) 22-36.

64. Matteri, R., J. Carroll and C. Dyer (2000). Neuroendocrine responses to stress. *The biology of animal stress: basic principles and implications for animal welfare* 43.

65. Matthews, L. R. and J. Ladewig (1994). Environmental requirements of pigs measured by behavioural demand functions. *Animal Behaviour* 47(3) 713-719.

66. McKeegan, D. and A. Philbey (2012). Chronic neurophysiological and anatomical changes associated with infrared beak treatment and their implications for laying hen welfare. *Animal welfare* 21(2) 207-217.

67. Mellor, D. and K. Stafford (2004). Animal welfare implications of neonatal mortality and morbidity in farm animals. *The veterinary journal* 168(2) 118-133.

68. Millar, H. (2018). A review of animal welfare policy and assessment frameworks. Report for Australian Eggs Limited. *Australian Eggs Limited Publication*. https://www.australianeggs.org.au/what-we-do/leading-research/a-review-of-animal-welfare-policy-and-assessment-frameworks/. Accessed December 2018.

69. Moberg, G. P. (1999). When does stress become distress? *Lab animal*.

70. Moberg, G. P. (2000). Biological response to stress: implications for animal welfare. *The biology of animal stress: basic principles and implications for animal welfare* 1 21.

71. Newberry, R. C., et al. (2007). Behaviour when young as a predictor of severe feather pecking in adult laying hens: the redirected foraging hypothesis revisited. *Applied Animal Behaviour Science* 107(3-4) 262-274.

72. Nicol, C. (2018). Feather pecking and cannibalism: Can we really stop beak trimming? *Advances in Poultry Welfare*. Elsevier. 175-197.

73. Nicol, C., et al. (2006). Effects of stocking density, flock size and management on the welfare of laying hens in single-tier aviaries. *British poultry science* 47(2) 135-146.

74. Pötzsch, C., et al. (2001). A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking, management and disease. *Applied Animal Behaviour Science* 74(4) 259-272.

75. Ralph, C., et al. (2015). Relationship between plasma and tissue corticosterone in laying hens (Gallus gallus domesticus): implications for stress physiology and animal welfare. *Domestic animal endocrinology* 50 72-82.

76. Rodenburg, T., et al. (2008). Welfare assessment of laying hens in furnished cages and non-cage systems: an on-farm comparison. *Animal welfare* 17(4) 363-373.

77. Rodenburg, T. B. and P. Koene (2003). Comparison of individual and social feather pecking tests in two lines of laying hens at ten different ages. *Applied Animal Behaviour Science* 81(2) 133-148.

78. Rushen, J. (2017). Housing and the welfare of dairy cattle. *In* J. Webster and D. Burleigh eds. *Achieving sustainable milk production*.

79. Rushen, J. and A. M. B. d. Passillé (1992). The scientific assessment of the impact of housing on animal welfare: a critical review. *Canadian Journal of Animal Science* 72(4) 721-743.

80. Sandoe, P., B. Forkman and S. B. Christiansen (2004). Scientific uncertainty-how should it be handled in relation to scientific advice regarding animal welfare issues? *ANIMAL WELFARE-POTTERS BAR THEN WHEATHAMPSTEAD-* 13 S121-S126.

81. Sapolsky, R. M. (2000). Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. *Archives of general psychiatry* 57(10) 925-935.

82. Sapolsky, R. M., L. M. Romero and A. U. Munck (2000). How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. *Endocrine reviews* 21(1) 55-89.

83. Sedlačková, M., B. Bilčik and Ľ. Košťál (2004). Feather pecking in laying hens: Environmental and endogenous factors. *Acta Veterinaria Brno* 73(4) 521-531.

84. Selye, H. (1955b). Stress and disease. *Science* 122(3171) 625-631.

85. Sherwin, C. and C. Nicol (1994). Dichotomy in choice of nest characteristics by caged laying hens. *Animal welfare* 3(4) 313-320.

86. Sherwin, C., G. Richards and C. Nicol (2010). Comparison of the welfare of layer hens in 4 housing systems in the UK. *British poultry science* 51(4) 488-499.

87. Shimmura, T., et al. (2010). Multi-factorial investigation of various housing systems for laying hens. *British poultry science* 51(1) 31-42.

88. Tilbrook, A. (2007). Neuropeptides, stress-related.

89. Tilbrook, A. and I. Clarke (2006). Neuroendocrine mechanisms of innate states of attenuated responsiveness of the hypothalamo-pituitary adrenal axis to stress. *Frontiers in neuroendocrinology* 27(3) 285-307.

90. Van den Bogaard, A., et al. (2001). Antibiotic resistance of faecal Escherichia coli in poultry, poultry farmers and poultry slaughterers. *Journal of Antimicrobial Chemotherapy* 47(6) 763-771.

91. Waiblinger, S., et al. (2006). Assessing the human–animal relationship in farmed species: a critical review. *Applied Animal Behaviour Science* 101(3-4) 185-242.

92. Waiblinger, S., et al. (2018). Human-hen relationship on grower and laying hen farms in Austria and associations with hen welfare. 52nd Congress of the International Society for Applied Ethology, Charlottetown, Prince Edward Island, Canada.

93. Walser, P. T. (1997). Einfluss unterschiedlicher Futterzusammensetzung und-aufarbeitung auf das Auftreten von Federpicken, das Nahrungsaufnahmeverhalten, die Leistung und den Gesamtstoffwechsel bei verschiedenen Legehennenhybriden. ETH Zurich.

94. Weeks, C. A., S. L. Lambton and A. G. Williams (2016). Implications for welfare, productivity and sustainability of the variation in reported levels of mortality for laying hen flocks kept in different housing systems: a meta-analysis of ten studies. *PloS one* 11(1) e0146394.

95. Windhorst, H. (2017). Housing system in laying hen husbandry-Part two. *Zootecnica International- Poultry Magazine*. https://zootecnicainternational.com/poultry-facts/housing-systems-laying-hen-husbandry-second-part.

8 Plain English Summary

Project Title:	Animal welfare and values
Australian Eggs Limited Project No.	1HS904
Researchers Involved	A.D. Fisher, P.H. Hemsworth, R.A. Ankeny, H. Millar, R. Acharya
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Objectives	Identify and describe values-based elements that arise from the available frameworks for animal welfare.
Background	Community or public values create expectations of how animals ought to be treated. These elements are a necessary intersection with animal welfare science but have the potential to affect the interpretation of the science, where assumptions can be made as to how scientific knowledge is created and how it should be applied.
Research	The identification of values was undertaken for key welfare topics, as follows: • natural behaviours – including dust-bathing, nesting, perching, and foraging • health – including skeletal health, feather cover, disease and mortality • stress • housing system – including cages, alternative housing systems • feather pecking and cannibalism • beak trimming • smothering • antibiotic use • management practices and stockmanship.
Outcomes	The project output comprises a report that captures the scientific analysis and values-based elements identified under the project scope, and the extent to which those elements could be the subject of focused research.
Implications	There are inevitable values-based judgements and considerations within the conduct and reporting of animal welfare science, and there are significant values-based questions and conflicts that emerge from animal welfare science, particularly as trade-offs between different components of animal welfare, which cannot be avoided. The key value conflicts and questions identified in this report provide the basis for researchable questions for future study, requiring the addition

	of social science into the stable of methodologies employed by the egg industry research program.
Key Words	welfare, laying hens, birds, values