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Review of evidence to underpin development of Welfare Standards and Guidelines

A focused review of science-based evidence on the welfare of Australian meat chickens

By Jean-Loup Rault and Lindsay Matthews

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Name: Jean-Loup Rault
Address: Alice Hoy building 162, room 003, Animal Welfare Science Centre, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville VIC 3010
Phone: 03 9035 7542
Email: raultj@unimelb.edu.au

Name: Lindsay Matthews
Address: Hollich 36, 48565 Steinfurt, Germany
Phone: +49 15 75 25 48 212
Email: lindsay.matthews1@gmail.com

RIRDC Contact Details

Rural Industries Research and Development Corporation
Building 007
Charles Sturt University
Boorooma Street
Wagga Wagga NSW 2650

C/- Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2678

Phone: 02 6923 6900

Fax: 02 6923 6999
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

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or phone 1300 634 313

Foreword

The development of Australian standards and guidelines for the welfare of poultry (including meat chickens) will likely be initiated over the coming year. These standards aim to reflect contemporary scientific knowledge, whilst simultaneously engaging competent animal husbandry and mainstream community expectations. There are no recent peer-reviewed papers that summarise the scientific knowledge currently available that can inform the processes of meat chicken welfare.

The aim of this project was to review and report on recent, relevant literature of meat chicken welfare, to ensure that the best verifiable information is available to inform the development of the Australian standards and guidelines.

This report provides a summary of current verifiable evidence regarding nine key topics that can potentially impact on meat chicken welfare: locomotion, leg and foot conditions, stocking density, meat chicken breeder feeding, thinning, light, environmental enrichment, free range production, and welfare monitoring. This was achieved through a systematic review of the relevant, recently published (2000-2014) literature on these key issues.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of the Chicken Meat R&D program, which aims to enhance the quality and safety of chicken meat products.

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John Harvey
Managing Director
Rural Industries Research and Development Corporation

About the Author

Dr Jean-Loup Rault is a Research Fellow with the Animal Welfare Science Centre, Faculty of Veterinary and Agricultural Sciences, at the University of Melbourne. He has an expertise in animal behaviour and stress physiology, specialising in poultry and pig welfare. His expertise has been recognised by his involvement in various poultry welfare scientist and industry forums, workshops, government institutions, as well as interventions to the public at large on the topic of poultry behaviour and welfare. He is also involved in developing novel methods of welfare assessment in poultry and other species, and assessing the welfare implications of particular housing systems or practices such as free range poultry production systems.

Dr Lindsay Matthews (Lindsay Matthews and Associates Research International) has over 130 published, refereed papers, over 120 other publications and 3 patents. He is currently working as an Animal Welfare Expert in Europe. He has wide international experience in livestock welfare research and its application to improve animal welfare. Recently, he has helped train competent authority veterinarians under the European Commission's Better Training for Safer Food programme on ways to assess and improve meat chicken and layer hen welfare and has participated as an invited expert to European Food Safety Authority (EFSA) animal welfare working groups. Previously, while based at a governmental research institute in New Zealand he was responsible for research programmes on several species including meat chicken welfare. Further, he was chair of the writing group responsible for developing the first meat chicken welfare code in New Zealand. Dr Matthews regularly provides national and international advice to government departments, and academic and industry organisations on animal welfare research and policy. For example, he has recently led an Objective in a European Food Safety Authority project to identify practical animal-based welfare measures for livestock.

Acknowledgments

The authors thank Rebecca Woodhouse for her help in conducting this work.

Abbreviations

D: Darkness

FCE: Feed conversion efficiency

FPD: Foot pad dermatitis

HB: Hockburn

L: Light

LED: Light-emitting diode

NGOs: Non-governmental organisations

OHS: Occupational health and safety

Contents

Executive Summary

What the report is about

This report provides a summary of up-to-date verifiable evidence regarding the nine key welfare topics, risk factors and husbandry practices that potentially impact meat chicken welfare: locomotion, leg and foot conditions, stocking density, meat chicken breeder feeding, thinning, light, environmental enrichment, free range production and welfare monitoring. This was achieved through a systematic review of the relevant, recently-published scientific literature.

Who is the report targeted at?

This report is targeted at all stakeholders of the Australian chicken meat sector. This includes the chicken meat industry, government and particularly policy and decision-makers, animal welfare groups, and anyone in the community at large that is interested in learning more about the scientific evidence underlying chicken welfare and the impact of various housing and management practices.

Where are the relevant industries located in Australia?

The chicken meat industry is located throughout Australia, and therefore this report is expected to have benefits at a national level.

Background

The development of Australian standards and guidelines for the welfare of poultry (including meat chickens) will likely be initiated over the coming year. These standards aim to reflect contemporary scientific knowledge, whilst simultaneously engaging competent animal husbandry and mainstream community expectations. As the standards aim to reflect up-to-date scientific knowledge, it is critical that such knowledge is readily available and from independent sources, to inform the process. Currently, there are no updated peer-reviewed papers summarising factors that potentially affect the welfare of meat chickens and associated risk factors.

Aims

The aim of this project was to review and report on recent, relevant literature on meat chicken welfare, to ensure that the best verifiable information is available to inform the development of the Australian standards and guidelines for the welfare of meat chickens.

Methods used

A systemic literature search was conducted using several literature databases, from the year 2000 to 2014.

An emphasis was placed on four factors:

- Studies conducted in commercial conditions were given more weight than those conducted in experimental (usually smaller scale) conditions, as these are more relevant to the field.
- Studies conducted in Australian settings were favoured over studies conducted overseas.
- Recent studies were given more weight than older studies, to account for the progress in genetic, environmental and management factors.
- The quality of the work was assessed objectively, and limitations that could be considered to potentially impact on the relevance or accuracy of the outcomes highlighted in the report.

Key findings

1. Locomotion

- While there is some variation between breeds, poor leg health is an important welfare concern in meat chickens. It occurs in significant proportions of birds in intensively-reared commercial meat chicken flocks overseas, but there is currently no equivalent data available for Australia.
- The level of welfare compromise caused by leg pathologies is typically assessed by measuring walking ability (gait scoring). There is a lack of a uniformity among the various ways that walking ability has been assessed, which raises concerns about the reliability of the results of the research.
- Moderate to severe walking impairment (Gait Score 3 and 4 on the Kestin *et al*. (1992) scale) cannot yet be used to differentiate between leg pathologies (and presumed painful conditions) or abnormal gait due to unbalanced body conformation.
- As a result of the extreme functional impairment in birds with Gait Scores 4 or 5, it is generally recognised that birds in commercial flocks with such scores should be humanely culled as soon as possible. The welfare implications of birds with Gait Score 3 or below require further clarification.
- The way a flock is sampled during gait scoring has a large impact on the observed prevalence of impaired walking ability, which raises questions about the correct way to sample and suggests ambiguity regarding the prevalence of varying levels of gait abnormalities that have been published.
- A variety of management practices can reduce walking impairments, however, a consideration is slowing growth early in life through the manipulation of feed composition or supply.

2. Leg and foot conditions

- In overseas studies, skin pathologies of the foot and leg are common welfare issues, the most prevalent being foot pad dermatitis (FPD).
- Prevalence levels of FPD in Australia are currently unknown, but the incidences observed in a limited sample of flocks in NSW are not inconsistent with overseas data. Several methods are used to quantify and record the incidence and severity of FPD, but there is no universally-accepted system. Further, the thresholds for welfare impacts have not yet been scientifically identified.
- Litter wetness (and possibly litter ammonia) has been identified as the main risk factor for FPD. Litter wetness is influenced by many different factors, including ventilation rates, litter type, drinker type, dietary composition, water intake and the breed of bird.
- Litter moisture levels between 20 and 25% help prevent FPD, however, a practical scoring system for litter requires refinement.
- Reductions in FPD prevalence have accompanied formal FPD assessment in Scandinavia.

3. Stocking density

- Stocking density is often regarded as one of the most high risk practices for meat chicken welfare and this is reflected in animal welfare legislation in many countries, including Australia.
- A large number of scientific studies have examined the effects of stocking density on chicken welfare in laboratory settings, but few studies have been performed in commercial production environments. A causal link between stocking density and chicken welfare is not yet clear, as many contradictory results have been reported across laboratory studies. An exception to this is a reasonably consistent increase in behavioural disturbance or associated conditions (such as scratches to the body) with increases in stocking density.
- In studies conducted under commercial conditions, stocking density has had little effect on several key welfare indicators (mortality, walking ability, skin conditions, jostling) at densities used in Australia. The absence of an effect of stocking density on mortality and an increase in behavioural disturbance at higher densities have been replicated in laboratory-based studies, although disturbance effects are reported to begin at lower densities in the laboratory. The reasons for the effect at lower densities in the laboratory are not clear and further replication in commercial production systems is required.

- In laboratory settings, it has been shown that birds kept at 40 kg/m^2 showed a strong motivation to move to an area of lower density (23 or 32 kg/m^2). Measures of the physical space requirements of birds indicate that they are compressed at densities above 40 kg/m^2. This suggests that future research is required to replicate studies on the motivation for space in commercial houses, in order to test the generalisability of these findings.
- Research on stocking density and chicken welfare has not been conducted recently under Australian conditions.

4. Meat chicken breeder feeding

- The industry currently employs a range of different controlled feeding regimens, which differ in the frequency of feeding, quantity or type of feed delivered.
- The welfare implications of the different feeding regimens for meat chicken breeders have not yet been fully examined.
- Attempts to develop a welfare methodology to assess feed motivation in meat chicken breeders have returned inconclusive results and the level of hunger experienced by breeders requires further research.
- Alternative feeding strategies that aimed at maintaining body weight control while improving welfare, have focused on diluting nutrient content, adding appetite suppression or altering protein levels in diets. Neither these strategies, nor environmental enrichment, appear to offer clear benefits for reducing feeding motivation.
- Genetic selection to reduce the need for controlled feeding may provide an avenue for future research to reduce the need for controlled feeding.

5. Thinning

- There have been no formal experiments on the effect of thinning on chicken welfare.
- The few studies that have been conducted, mostly epidemiological investigations, showed major scientific limitations. It is not possible to ascribe cause-and-effect from epidemiological studies.
- The consequences of thinning have been associated with improvements, declines and no change in the welfare status of birds remaining in the flock.
- Further research using controlled experimental studies is required before the welfare impacts of thinning can be confidently assessed.

6. Light

- Light exposure is a complex topic because it includes several characteristics (photoperiod, light intensity, wavelength and light source), which can have main or interactive effects.
- While constant or near-constant light (e.g. 23 to 24 hours) increases growth, birds under shorter photoperiod usually show compensatory growth and similar final body weight.
- Lower mortality, lower incidence of diseases from metabolic or skeletal origins, and behavioural changes are usually reported to be associated with shorter photoperiods. However, studies on photoperiods offering 14 hours of light or less often report activity during the dark periods.
- The distribution of the light cycle (e.g. alternate day and light periods of various durations) may be important, but, comparatively, has received little attention.
- Some effects of photoperiod on welfare may be indirectly attributable to alterations in growth pattern rather than light per se, as lighting is not the only way to reduce growth rate.
- Interpretation of the literature on the effects of photoperiod is further complicated by the practice of step-down and step-up programs, which have received little scientific investigation.
- There is still considerable discrepancy regarding the effects of various light intensities on meat chicken behaviour and welfare, although, there is agreement that light intensity below 5 lux causes changes in eye morphology.
- The light intensity contrast between light and dark periods appears important, and proves to be a limitation for the interpretation of results from some studies.

- The determination of an optimal light intensity for bird welfare is further complicated by the fact that birds seem to have different preferences at different ages.
- Few studies have investigated the welfare implications of behavioural changes induced by varying light programs, and whether these changes have an affect on common welfare criteria such as mortality, gait scores and leg health, FPD, hockburn (HB) or scratches on the body.
- Little is known about the influence of various light sources, the welfare implications of providing progressive light program transitions at dawn and dusk, and the influence of natural light.

7. Environmental enrichment

- There is limited evidence in the literature that the provision of perches strongly benefits meat chicken welfare. In general, perches appear poorly used, either because of their design, placement, the bird's heavy weight or other factors.
- Other enrichment strategies, such as the provision of straw bales or devices that birds can peck, have had variable success in terms of use by the birds, but any welfare benefits are still unclear.
- Overall, the welfare implications of environmental enrichment programs require further investigation in commercial settings to account for the myriad of variables that influence meat chicken behaviour and welfare.

8. Free range production

- The use of the outdoor range by meat chickens is highly variable across farms and across flocks on the same farm.
- More data needs to be collected in different types of localised Australian conditions, particularly because use of the range is largely affected by weather conditions, and most of the studies to date have been conducted in Northern European conditions.
- Cover placed close to the shed can attract chickens in the range, but they are generally reluctant to venture more than 10 to 20 m away from the shed, even when cover is provided.
- Comparative studies have shown that slow-growing strains range considerably more than fast-growing strains.
- Despite its practical relevance, the effects of outdoor access on immunology and disease prevalence have been the subject of little scientific study, either experimental or epidemiological.
- Overall, little research has been done on individual chickens in commercial flocks to understand the welfare implications of using the outdoor range. Further, the limited research that exists is sometimes contradictory.

9. Welfare monitoring

- Internationally, welfare monitoring of meat chickens has been used for several different purposes, such as assessing compliance with legislation or policies of producer groups (e.g. integrated producer companies), food supply companies (e.g. quick service restaurant chains or supermarkets) or welfare interest groups (e.g. non-governmental organisations [NGOs]).
- Surveillance programmes designed to ensure continuous welfare improvement should incorporate aspects that ensure timely engagement by farmers, timely and solution-orientated feedback, and may not require specific performance thresholds.
- Measures of the risks to welfare associated with the production facility, birds and management, together with an assessment of the welfare outcomes for the birds, are desirable features of monitoring schemes as shown in the Swedish system for monitoring FPD.
- Designing a monitoring protocol that allows benchmarking by producers is potentially an effective way to achieve continuous improvements in welfare.
- Monitoring protocols used for compliance purposes require identification of thresholds for acceptable/unacceptable performance, yet validated thresholds do not yet exist. Nonetheless, sanction-based systems have had some success in improving welfare performance.
- Outcome-based welfare measures should be tested for validity, repeatability, reliability and standardisation, together with validation of flock sampling procedures.

- Time-efficient and cost-effective monitoring tools, possibly using novel automated recording systems, are required to ensure rapid adoption by producers.

Implications

The literature summarised in this report covers key welfare topics, risk factors and husbandry practices that potentially impact meat chicken welfare and provides a critical review of the available information. The review shows that there is a lot of uncertainty regarding the types of management practices and housing conditions that impact adversely on welfare. Similarly, most measures of welfare and thresholds for acceptable welfare are not well validated. Thus, modifications to the Code will need to be considered carefully.

In the process of the review, it became clear that there is a paucity of published information on Australian housing and management practices and evaluation of chicken welfare under local conditions. In countries that use housing systems and breeds similar to those in the Australian chicken meat industry, several welfare topics are common (as identified in this report), although welfare outcomes vary between farms and countries. Therefore, collecting scientific information under local conditions would help assess the extent and relevance of each of the topics (and associated risk factors) covered in this report to Australian meat chickens. It would also help to identify where improvements could be made.

Stockmanship is widely acknowledged as one of the most important determinants of an animal's welfare, and on a general level is linked to all aspects of welfare covered in this literature review. Despite its importance, stockmanship has received little attention in scientific studies on chicken welfare, and little published information could be found on the topic.

Recommendations

- This report provides a summary of the current verifiable evidence regarding key issues and risk factors for meat chicken welfare. The report relies mostly on international published evidence because there is little published data with meat chickens under Australian conditions for the topics covered in this literature review.

- The housing conditions and breed of birds used for meat chicken production are relatively standard throughout the developed world. Not surprisingly then, the risk factors and welfare concerns tend to be similar across these production systems. Thus, while there has been little formal evaluation of meat chicken welfare in the Australian industry, the international scientific literature serves as a useful platform for informing the review of the Model Code of Practice - Domestic Poultry and/or to support the development of standards and guidelines for poultry welfare.

- A list of potential welfare indicators could be developed based on the verifiable evidence regarding key issues on meat chicken welfare discussed in this report. However, further knowledge about the risk factors and relevance of various welfare issues in the Australian chicken meat industry would be helpful for the development of welfare indicators relevant to the local industry.

- Suggestions to improve welfare through monitoring and benchmarking does not necessarily equate to increasing the amount of auditing protocols or compliance schemes. Indeed, the industry already collects detailed data on bird growth, health, mortality and environmental parameters. This data, if systematised, could be used to benchmark chicken welfare and to monitor progress.

- Traditionally, welfare risks and management have focussed on conditions during rearing. Nonetheless, experience shows that it is not only what happens in the grower shed, but also at the meat chicken breeder stage, hatchery, the quality of feed and the transport and slaughter processes that all ultimately impact on the welfare of meat chickens. Hence, a whole-of-life/whole system approach is required to achieve the best outcomes for meat chicken welfare in Australia.

Introduction

The development of Australian standards and guidelines for the welfare of poultry (including meat chickens) will likely be initiated over the coming year. These standards aim to reflect contemporary scientific knowledge, whilst simultaneously engaging competent animal husbandry and mainstream community expectations. The standards will specify acceptable animal welfare requirements that must be met under law for livestock welfare purposes. The standards are intended to be clear, essential and verifiable statements (although it is recognised that not all issues are able to be well-defined by scientific research). The process will also produce guidelines, which are recommended practices to achieve desirable animal welfare outcomes. The guidelines will complement the standards and should be used as guidance only i.e. non-compliance with one or more guidelines will not in itself constitute an offence under law.

As the standards aim to reflect up-to-date scientific knowledge, it is critical that such knowledge is readily available, and from independent sources, to inform the process. There are currently no updated, peer-reviewed papers summarising the welfare of meat chickens and associated risk factors in Australia.

The aim of this project was to review and report on recent, relevant literature on meat chicken welfare, to ensure that the best verifiable information is available to inform the development of the Standards and Guidelines of Australia.

Objectives

This project provides a summary of the up-to-date verifiable evidence regarding nine welfare topics, risk factors and husbandry practices that potentially impact meat chicken welfare: locomotion, leg and foot conditions, stocking density, meat chicken breeder feeding, thinning, light, environmental enrichment, free range production, and welfare monitoring. Most of these topics will be seen as a potential negative impact on welfare, but other practices aim to positively affect chicken welfare.

These objectives were achieved through a systematic review of the relevant, recently-published scientific literature on the key topics as related to bird welfare in the chicken meat industry.

Methodology

A systemic search of recent literature was conducted using several scientific databases; including Web of Science, PubMed and Google Scholar. The keywords "broiler*" OR "meat chicken*" AND "Animal Welfare" were used for every search, with more specific search key word terms added according to each topic. The search range was restricted from 2000 to 2014, but papers published before 2000 that were deemed relevant or useful were included.

Examples of keywords included in the specific searches are presented below:

- Locomotion – "Locomotion" OR "gait" OR "walking ability" OR "leg weakness" OR "mobility" OR "leg problems" OR "lameness".
- Leg and foot conditions – "Podo dermatitis" OR "podo-dermatitis" OR "Foot pad dermatitis" OR "hock burn" AND "litter quality".
- Stocking density – "Space allowance" OR "stocking density" OR "group size".
- Meat chicken breeder feeding – "Broiler breeder" OR "breeder" OR "controlled feeding" OR "restricted feeding" OR "hunger" OR "feed*" OR "restrict"* OR "motivation" OR "feeding behaviour".
- Thinning – "Thin"* OR "harvest*" OR "catch*" OR "depopulation".
- Welfare monitoring – "Cull*" OR "benchmark*" OR "protocol" OR "measure*" OR "assess*".
- Light – "Light*" OR "duration" OR "intensity" OR "length" OR "photoperiod" OR "natural" OR "scheduling" OR "dark period" OR "light type".
- Environmental Enrichment – "Environmental enrichment" OR "enrichment" OR "perch*" OR "activity".
- Free range – "Outdoor" OR "range" OR "pasture" OR "free* range" OR "free range" OR "run".

More specific searches using additional key words were conducted when only a few references were initially found for a particular topic.

During the systematic literature search, an emphasis was placed on four factors:

- Studies conducted in commercial conditions were given more weight than those conducted in experimental (usually smaller scale) conditions, as these are usually more relevant to the field.
- Studies conducted in Australian settings were favoured over studies conducted overseas.
- Recent studies were given more weight than older studies, to account for the progress in genetic, environmental and management factors.
- The quality of the work was assessed objectively, and limitations that could be considered to potentially impact on the relevance or accuracy of the outcomes highlighted in the report.

1. Locomotion

Issues and Monitoring

Poor leg health is an important welfare concern in meat chickens as it typically occurs in significant proportions of birds in intensively reared commercial meat chicken flocks in all countries studied (see EFSA (2010a) and de Jong *et al.* (2012a) for recent reviews). The vast majority of research on this topic has been conducted in Europe and North America, with a small and increasing number of publications from Brazil and elsewhere, with few papers from Australia. Leg deformities are caused by metabolic, developmental and infectious factors (see review by Butterworth and Haslam, 2009). These, in turn, are associated with a large range of other features of the birds' genetic, dietary and general environment, physiological status and sex (Butterworth and Haslam, 2009). Under commercial conditions, several factors may interact to influence leg health, so laboratory-based results are often not readily transferable to the field and it is therefore difficult to identify cause-and-effect relationships in commercial flocks.

Nevertheless, management-based risk factors for leg weakness have been reported. The key factors are high stocking density, too high or too low environmental temperature or humidity, long photoperiod, very low light intensity, inappropriate diet, barren environment, fast growth rate, high body mass, reduced mobility, inappropriate incubation practices and poor hatchery hygiene (de Jong *et al*., 2012a; Dawkins *et al*., 2004). However, the relative importance of these factors is subject to debate. For example, Dawkins *et al*. (2004) showed that, for stocking densities of 30 to 38 kg/m^2, leg weakness as measured by leg culls and gait score (see below for a critique of gait scoring) was not related to stocking density *per se* under commercial conditions and that environmental temperature and humidity were more important determinants of variation in leg health. Similarly, shorter dark periods have been associated with poorer leg health in some studies (Schwean-Lardner *et al.,* 2013), but not in others (Brown, 2010). Fast growth and high body mass are more reliably associated with leg weakness (EFSA, 2010a). Variations in incubation temperature have (inconsistently) been associated with leg abnormalities (de Jong *et al*., 2012a). Recent research suggests incubation temperature effects may be mediated via the duration of the incubation period (e.g. Groves and Muir, 2014), with slightly lower than recommended temperatures during the first 15 days of incubation being associated with greater leg strength, as measured by a latency-to-lie test. The effect of incubation practices requires further research (de Jong *et al*., 2012a). Interestingly, Paxton *et al*. (2013) has hypothesised that an uneven gait due to unbalanced body conformation might also be a risk factor for the development of leg pathologies.

The level of welfare compromise caused by leg pathologies is typically assessed by measuring walking ability by gait scoring. The most frequently-used methodology is that developed by Kestin *et al.* (1992), where mobility is rated on a 6-point scale; 0 = normal gait; 1 = slight defect no functional loss; 2 = identifiable defect with no functional loss; 3 = obvious defect, such as a limp or unsteady strut, which affects the birds ability to move; 4 = severe gait defect and walks only with difficulty; 5 = incapable of sustained walking on the feet (see Kestin *et al.* (1992) for a full description). Several other gait scoring methodologies have also been used (e.g. Dawkins *et al*., 2004; Webster *et al*., 2008), with slightly different definitions and fewer categories. In addition, latency-to-lie (in a pool of water) (Berg and Sanotra, 2003) and measures of forces exerted whilst walking have also been evaluated (Refatti, 2013; Sandilands *et al*., 2011). The lack of uniformity between these various measures in comparative studies raises concern about the reliability of the data (Refatti, 2013; Webster *et al.*, 2008). Of more concern is the mounting evidence from studies designed to test the validity of the Kestin *et al.* (1993) protocol. This research has shown that moderate to severe walking impairment (Gait Score 3 and 4 on the Kestin *et al* scale) cannot yet be used to differentiate between leg pathologies (and presumed painful conditions) and abnormal gait due to unbalanced body conformation (de Jong *et al*., 2012a; Hothersall *et al*., 2012, 2014; Caplen *et al*., 2013, 2014;

Sandilands *et al*., 2011; Siegel *et al*., 2011; Skinner-Noble and Teeter, 2009). Nevertheless, as a result of the extreme functional impairment in birds with Gait Scores 4 or 5, it is generally recognised that birds in commercial flocks with such scores should be humanely culled as soon as possible (EFSA, 2010a). The welfare implications of birds with Gait Score 3 or below require further clarification.

Recent research by Marchewka *et al*. (2013) has raised another important issue in the application of gait scoring methodologies. This work has shown that the flock sampling procedure has a large impact on the observed prevalence of impaired walking ability. Traditional measures using the Kestin *et al*. (1992) methodology are made using samples of birds caught within a small portable arena. The birds are scored as they are released one at a time from the pen. Birds reluctant to walk are gently prompted with a goad. Marchewka *et al*. (2013) compared the Kestin *et al*. (1992) sampling procedure with another, less invasive method, wherein the gait of individual birds is scored as they are encountered by an observer walking slowly in a straight line the length of the shed (transect). This technique mimics that used by growers in their regular flock inspections. Using the Kestin *et al*. (1992) procedure, the percentages of lame (Gait Score 3) and immobile birds (Gait Score 4 and 5) was 24.2 and 4.7 %, respectively. With the Marchewka *et al*. (2013) transect sampling methodology, the respective percentages were 0.8% and 0.2%. Differences in the way the birds are selected (corralling versus natural encounter) may account for the observed differences, as chickens with reduced mobility may be easier to catch. Encouragement of the birds to walk in the Kestin *et al*. (1992) procedure may also affect the observed prevalence. For example, Cordeiro *et al*. (2009) reported that the observed gait score is higher for birds that are not encouraged to walk. Cordeiro *et al*. (2009) also showed that using a sample size of only 10 birds in a flock (as used by Dawkins *et al*., 2004) produces highly variable measurements. In addition, Webster *et al*. (2008) have reported relatively poor correlations between the Kestin *et al*. (1992) 6-point scale and a simplified 3-point scale.

All considered, recent research shows that the various gait scoring systems and associated sampling procedures are not sufficiently well-validated to allow robust quantification of the prevalence and degree of welfare compromise in gait impaired meat chickens. Since the incidence of leg pathologies is generally acknowledged as a major and ongoing issue in the chicken meat industry (e.g. EFSA, 2010a), it is important that a practical and accurate methodology for assessing the welfare impacts of such pathologies is refined as soon as possible. Automated systems based on flock movement or distribution patterns are currently under evaluation and offer promise (e.g. Dawkins *et al*., 2012). De Jong (2013) has suggested that measures of walking ability could be replaced by measures of severe hock burn (HB), since the two are correlated. However, the correlations were not particularly strong and there is insufficient scientific evidence to use HB score as a proxy for walking ability.

Notwithstanding issues with the validity of the various gait scoring systems, within studies where a single methodology has been consistently applied, a wide variation in the prevalence of gait abnormities is often seen between farms. For example, in the UK and Denmark commercial production systems, Dawkins *et al*. (2004) reported a mean prevalence of abnormal gait (Scores 1 and 2) of 23.4% and a between-farm range of 0 to 90%. Similarly, Bassler *et al*. (2013), using the Kestin *et al*. (1992) scoring procedure on farms in France, Italy, the Netherlands and the UK, reported the 5th percentile prevalence was 0.5% for Gait Score 3 and over, and the 95th percentile prevalence was 52%. Thus, there are commercially produced flocks which have very low levels of poor walking ability. Effective culling policies are not likely to account for all of the between-farm differences, as birds with Gait Scores of 4 and 5 are typically culled, but not birds with Gait Scores of 3. Given that the genetics of the birds are similar across many farms, it would seem that it is possible to achieve good bird mobility through animal and environmental management.

Management practices

Butterworth and Haslam (2009) have provided a good summary of management practices that can be used to reduce the incidence of leg pathologies. A first step is to institute rigorous culling of birds that are unable to walk, or that have great difficulty in doing so. Slowing growth, especially in the first weeks of life, through manipulation of feed composition or supply, can help to reduce leg disorders (de Jong *et al*., 2012a; Butterworth and Haslam, 2009). For example, mash as opposed to pelleted feed, or inclusion of whole wheat in the diet, will reduce intake. Further, restricting feed quantity, nutrient density or time of availability (directly or through the lighting programme) can also slow growth. It is interesting to note that in a large and recent epidemiological study of intensive commercial meat chicken production systems conducted across several European countries, only two management factors were associated with walking impairment (Bassler *et al*., 2013); increasing flock age was associated with poorer walking ability, and mobility increased with longer dark periods. Other factors such as stocking density, litter quality, light intensity and thinning (partial depopulation during the rearing period) were not associated with walking ability.

Reduced immune challenges during early development (e.g. lower rates of disease incidence or vaccinations) are perhaps an under-exploited management practice that shows promise for reducing leg pathologies, as healthier birds can allocate a greater proportion of resources to bone development (Dibner *et al*., 2007).

2. Leg and foot conditions

Skin pathologies (contact dermatitis) of the foot and leg are important direct and indirect criteria for meat chicken welfare because:

- When measured, the prevalence is often high (see below),
- They reflect the adequacy of the litter substrate, ventilation and many other aspects of the physical environment and management,
- In their more severe forms, they most likely indicate an unacceptable level of welfare compromise.

Most of the recent scientific and practical information on the welfare implications of skin disorders has been summarised by Shepherd and Fairchild (2010), and de Jong *et al*. (2012a, 2013). An earlier review by Berg (2004) also remains useful. The vast majority of research on this topic has been conducted in Europe and North America, with relatively few publications from elsewhere, including Australia. The condition of the litter is key in achieving good skin health; Dunlop (2014) has provided a good practical summary of litter characteristics and performance in rearing meat chickens.

The two most common skin disorders are footpad dermatitis (FPD) and HB, with breast blisters typically much less common. The various forms of skin disorder tend to be associated (Martland, 1985), although, FPD is usually more common than HB. Recent studies across several European countries have reported a median prevalence for moderate/severe FPD of 33 % (mean 37%), and moderate/severe HB of 2% (mean 8%) (Bassler *et al.*, 2013). There are no published reports of the prevalence of FPD and HB across the whole Australian chicken industry, but a 2014 report by Cressman *et al.* (2014), using a very small sample of farms in New South Wales, showed that FPD (moderate/severe) was present in 36% of birds on standard (new) litter, and HB was found in 80-75% of birds. The high level of HB in the Cressman *et al.* (2014) study compared to other studies may have been due to differences in the definition of HB. Thus, as with other countries, it would seem that skin pathologies are also an important welfare issue in Australian commercial chicken meat production systems. Since both FPD and HB appear to have a similar aetiologies (with the exception that HB is additionally influenced by the liveweight; DEFRA, 2010) and FPD is better researched.

There are large variations within and between farms and between countries in the reported prevalence of FPD, ranging from 1 to 91% for the 5th and 95 percentiles, respectively (e.g. Bassler *et al*., 2013). The low average incidence of FPD in some farms and countries (e.g. New Zealand, Bagshaw *et al*., 2006), and the sharp reductions achieved on Danish farms over recent years (Kyvsgaard *et al*., 2013), demonstrate that it is possible to achieve high levels of leg health within commercially viable systems. Kysvgaard *et al*. (2013) attribute the improvements in Denmark to reduced water spillage and thorough heating of houses prior to stocking (to reduce condensation in the litter) and the use of wood shavings in place of chopped straw.

FPD is characterised by inflammation and necrotic lesions which may be superficial or deep (e.g. Michel *et al*., 2012) and, thus, is assumed to be an important indicator of welfare compromise. Due to the inflammatory and other pathological characteristics of the lesions, many authors have assumed the condition to be painful (e.g. de Jong *et al*., 2012a). However, there is little direct evidence to support this view. A study (DEFRA, 2010) has shown that the presence of foot and hock lesions is associated with a reluctance to walk, but the authors concluded that this effect could not be unambiguously attributed to pain, as treatment with analgesics did not reliably improve motivation to walk. Similarly, Hothersall *et al*. (2011) reported the absence of hyperalgesia (a response normally associated with inflammatory pain) in birds with FPD. In contrast, Caplen *et al*. (2014), using latency-to-lie as a measure of mobility, found that birds with higher FPD were quicker to lie down, perhaps suggesting that FPD causes discomfort. However, since latency-to-lie was not measured prior to the development of FPD, a short latency-to-lie may be a cause of FPD rather than a consequence. Therefore, latency-to-lie is not an unconfounded measure of discomfort. The relationship between FPD scores and productivity is variable (e.g. Dawkins, *et al*., 2004; de Jong *et al*., 2014). The welfare implications of different degrees of severity of FPD and HB remain to be fully elucidated.

Litter wetness (and probably litter ammonia; DEFRA, 2010) is the primary cause of FPD (e.g. de Jong *et al*., 2014), therefore, FPD is a good indicator of litter quality. Many factors potentially impact on litter quality including (see review by Shepherd and Fairchild, 2010):

- Litter type, size, depth and texture,
- Drinker design and management,
- Dietary ingredients (as these contribute to variations in water intake, the amount of faeces produced and their water content and viscosity),
- Gut health,
- Ambient conditions (poor ventilation and high humidity under cold conditions, winter/autumn seasons typically give higher FPD),
- Ventilation,
- Lighting regimes,
- Activity,
- Strain of bird,
- Stocking density.

Notably, cause-and-effect relationships between such factors and FPD are often difficult to demonstrate. There are a number of reasons for this:

- Many factors interact to cause skin pathologies and experimental settings typically do not fully replicate the complexity of commercial conditions. Thus, the results from laboratory-based studies will be heavily influenced by the particular (sub) set of factors chosen.
- Partly in recognition of the limitations of laboratory-based studies, many researchers have used epidemiological methodologies in commercial settings to attempt to identify factors related to FPD. While these studies have provided important information about correlations between hazards and skin disorders, causation cannot be inferred from epidemiological methodologies.

Not surprisingly then, the importance attributed to a variety of hazards varies greatly between studies.

Litter wetness is a function of the amount of moisture applied, litter absorptive capacity and/or its drying rate (for a useful summary of practical information see Dunlop (2014); Bilgili *et al*. (2009)). Chicken excreta are the main source of water input to litter, but localised wet areas occur around water spillage from drinkers. Ingress of water from outside the building, especially in older buildings (DEFRA, 2010), and moisture from the air also contribute to litter wetness. A litter moisture level of 15 to 30% is generally recommended (e.g. Dunlop, 2014; McGahan and Tucker, 2003) and 20 to 25% may be ideal (Bowen *et al*., 2010), ensuring that the litter is neither too dry (which encourages dust and respiratory health problems) nor too wet. In practice, these levels may not be achieved frequently. In one survey in the US, three-quarters of the growing houses surveyed had average litter moisture contents above 30% (Hayes *et al.*, 2000). Wet litter often becomes caked, with non-caked litter having a moisture content of about 25 to 30%, while caked litter has a moisture content almost twice as high (45 to 48%) (Sistani *et al*., 2003). The published literature indicates that a high proportion of the litter in a house can become caked during rearing. For example, in several European countries, Bassler *et al*. (2013) reported a median litter score of 3 (where approximately 50% of the litter is non-friable) on the scale developed by Tucker and Walker (1992). In a USA study, Sistani *et al*. (2003) calculated that 43% of the litter was caked.

Litter moisture content varies systematically throughout the house, but there have been few scientific studies to quantify this variation. Tasistro *et al*. (2004) and DEFRA (2010) reported average litter moisture of 15 to17% at feeders, 50 to 55% at drinkers and 27 to 30% elsewhere. Typically, moisture levels have been assessed by averaging measures taken from several sampling sites within the house.

Average measures may give a false impression of the risk of development of FPD due to the spatial variation in litter moisture content. For example, Cressman (2014) reported 23% of birds with FDP at age 14 days, yet average litter moisture was relatively low at 29.5%. Localised areas of high moisture litter possibly contributed to the FPD, as caking was reported around the drinkers and elsewhere.

The relationship between variation in moisture content across different regions of a shed and the prevalence of skin disorders has not been determined. Maintaining litter moisture levels at less than 30% throughout the shed is likely to be the best strategy for controlling FPD and related pathologies. Recent research has shown that *Campylobacter* infection of meat chickens is not as benign as previously thought, and can lead to poor gut health, wetter litter and higher prevalence of FPD (Williams *et al*., 2013).

Regarding litter type, there is a lot of variation in the incidence of FPD between materials. Of those in common use, wood shavings is typically the best, followed by rice hulls (although Almeida Paz *et al*. (2012) observed that rice hulls performed better than wood shavings) and saw dust (Grimes *et al*., 2002). All of these materials are used in Australia (Robins and Phillips, 2011). Chopped straw is also used in in Australia (Robins and Phillips, 2011) which, in other countries, is often associated with higher levels of FPD (e.g. Berk, 2009). Some newer materials, such as Pelletinos (chopped straw compacted into pellets at high temperature), also perform well (Berk, 2009). Re-use (which may be partial or total) of litter across multiple batches is common in some parts of the world (e.g. USA, Shepherd and Fairchild, 2010). The foot health of the birds on re-used wood shavings in Australia was comparable with that of chickens reared on fresh litter (Cressman, 2014), but the moisture content of both fresh and re-used wood shavings in Australian studies has been reported to exceed 30% later in the rearing period (Cressman, 2014; Islam *et al*., 2013 a, b). Re-use of both rice hulls and wood shavings increased FPD in Brazil (Almeida Paz *et al*., 2012). Several new materials and litter amendment treatments have been evaluated (e.g. Bilgili *et al*., 2009), with mortar sand and ground door filler associated with lower FPD rates than wood shavings. The availability and cost of alternatives require consideration.

Reductions in water spillage can be achieved by the use of nipple drinkers with cups (instead of just nipple drinkers), lowering the water pressure during colder seasons or early in the rearing period and adjusting the nipple heights so that they are not too low (Shepherd and Fairchild, 2010; de Jong *et al.*, 2013). Interestingly, sheds with nipple drinkers (compared to bell drinkers) were correlated with a higher proportion of scratches on the carcasses (Allain *et al*., 2009). Although, it is not clear if the relationship is cause-and-effect, this result highlights the importance of carrying out a comprehensive welfare assessment when evaluating the advantages and disadvantages of husbandry systems.

Variation in dietary protein has been shown to be associated with FPD prevalence, ranging from 10 to 97% (DEFRA, 2010). Excessive dietary protein likely influences FPD development by raising litter nitrogen and litter water content (as high dietary protein stimulates water excretion). Thus, the litter is poorer quality, not only because it is wetter, but also because it combines with the higher nitrogenous levels to increase ammonia release (DEFRA, 2010). Other dietary factors associated with poor litter quality include non-starch polysaccharides, high dietary sodium and deficiencies in biotin and trace minerals (see, for example, Cengiz *et al*., 2012; de Jong *et al*., 2013; Manangi *et al*., 2012; Shepherd and Fairchild, 2010).

The relationship between several different factors and FPD are inconsistent. These include stocking density, lighting regimes and exercise. In a recent epidemiological study of commercial flocks across countries in Europe, no association was found between stocking density and FPD (Bassler *et al*., 2013), while in other studies on commercial flocks within the UK (Haslam *et al*., 2007) and Denmark (Kyvsgaard *et al*., 2013) weak associations were reported. The most likely reason for the absence of a consistent effect of stocking density on skin disorders is that management factors other than stocking density, such as ability to control ventilation of the house, are more important factors in maintaining litter quality and, therefore, leg health (Dawkins *et al*., 2004).

Lighting parameters may also effect FPD. Severe lesions are reported to increase at light intensities below 5 lux. Schwean-Lardner *et al*. (2013) reported that average FPD score increased with increasing day length (14 to 23 hours), but day length had no effect on the incidence of moderate or severe FPD and no association between length of dark period and FPD has been seen in commercial flocks (Bassler *et al*., 2013; Knowles *et al*., 2008). More exercise has been suggested to reduce FPD, but the effect is inconsistent. For example, Sherlock *et al*. (2010) found no relationship between individual bird activity levels and incidence of skin conditions.

Recent work indicates that the standard rate of temperature decline may cause higher rates of FPD than a slower rate of decline (van Harn and de Jong, 2012). Breeder feeding and egg incubation regimes alter the development of the offspring foot pads, with potential implications for FPD, but this has yet to be determined (Da Costa *et al*., 2014).

Practical strategies to improve litter quality and resistance to development of FPD

Strategies to improve leg health can be achieved by improvements to bird and litter management and genetic selection of birds, with the former being the most applicable for growers. As a first step, robust and practical measures of litter moisture content and skin conditions are required so that improvements in litter quality can be quantified.

Several subjective measures of litter quality that purport to assess the moisture have been proposed: a 5-point scale varying in the extent of caking (Tucker and Walker, 1992); a 5-point scale ranging from a score 0 (completely dry and flaky, moves easily with foot) to 4 (sticks to boots once the cap or compacted crust is broken) (Welfare Quality, 2009); the degree of adhesion when a handful of litter is squeezed (Bowen *et al*., 2010), if it will not adhere at all it may be too dry, if it adheres slightly it has the correct moisture content, and if it adheres tightly and remains in a ball it is too wet. There is also the American Association of Avian Pathologists Inc. (2014) procedure, that assigns scores out of 100 (0 = worst and 100 = best) in each of the following categories: size and location of areas of caking, friability as measured by dustiness and stickiness when compressed, particle texture/size, and ammonia concentration.

None of the methodologies have been scientifically validated, although all appear to have some validity. Increases in FPD are correlated with increases in the Tucker and Walker (1992) litter score (Haslam *et al*., 2006; Bassler *et al*., 2013). The American Association of Avian Pathologists Inc (2014) system is the most comprehensive, in that it takes into consideration a variety of litter features that influence FPD development, but thresholds that provide for good welfare remain to be determined. Given that it is difficult to avoid caking in considerable areas of the shed (see section 2. Leg and foot conditions above), it is particularly important to determine the relevance of the location and extent of caked areas to the development of FPD. Such information is also critical for determining appropriate litter sampling procedures.

There is no single standardised system for scoring FPD foot and leg health. Research methodologies are normally based on manual inspection and scoring the size and severity of lesions (see Michel *et al*., 2012). For practical purposes on farms or slaughter plants, most schemes are based on a variant of the Swedish 3-point scoring system scoring system (Berg, 2004), where 0 = no or very superficial lesions, 1 = mild lesions, and 2 = severe lesions (see Berg, 2004) following manual inspection.

For legislative reasons, in Sweden and Denmark the foot pad scores (of a sample of ten birds from each flock) are transposed into a flock score. The flock score is calculated by multiplying the number of birds assigned a Score 1 by 0.5, multiplying the number of birds assigned a Score 2 by 2, and summing these two values (Danish Centre for Animal Welfare, 2011). The flock score ranges from 0 (all birds with no lesions) to 200 (all birds with score 2). The Danish legislation sets thresholds for different levels of welfare compromise: a flock score of 40 or below is considered acceptable; a score of 41 to 80 results in a notice to the grower to improve management; and a score over 80 leads to a notice to the grower to improve management as well as formal notification of the veterinary authorities (Kyvsgaard *et al*., 2013). The mean flock lesion score has declined from approximately 100 to 40 since the introduction of the formal scoring process ((Kyvsgaard *et al*., 2013). While the scoring system appear valid, the scientific validity of the thresholds used to distinguish different levels of welfare compromise remains to be assessed.

Automated footpad health scoring systems for installation in slaughter plants are under development in several countries and offer the advantage of rapid throughput, but are not yet fully reliable (de Jong, 2013; Vanderhasselt *et al*., 2013).

De Jong *et al*. (2013) have provided a comprehensive and up-to-date summary of practical tools to maintain good litter quality. The important and/or novel methods include:

- Maintaining relative humidity in the range recommended by the breeder companies, especially early in the life of the birds (first 2-3 weeks, Dawkins *et al*., 2004). Note that litter amendments to reduce litter acidity and ammonia levels have been evaluated, including under Australian conditions, but without consistent success in reducing FPD (e.g. Cressman, 2014),
- Control of water spillage,
- Feeding a properly balanced diet, decreasing non-starch polysaccharide levels and adding insoluble fibres to wheat-based diet (van der Hoeven-Hangoor *et al*., 2014),
- Adding barriers that also serve as perches is a novel approach (Ventura *et al*., 2010, 2012). In recent small pen trials, such barriers reduce contact with litter and lead to a more even distribution of birds and could potentially lead to better litter quality and less FPD,
- Emergence of strains resistance to FPD while maintaining high productivity (DEFRA, 2010; Ask, 2010; Kapell *et al*., 2012) provides another sustainable solution for foot pad dermatitis.

3. Stocking density

Stocking density of meat chickens is typically measured in kilograms body weight of live birds per square meter of floor space in the rearing shed. Animal welfare experts regard stocking density as one of the production practices that creates a high risk for bird welfare (EFSA, 2010a). The experts highlighted many potential adverse effects on chicken welfare, including; increased disease transmission; reduced air quality; poor litter quality and associated skin conditions (e.g. FPD); disturbed rest; movement restriction; heat stress; reduced behavioural repertoire; and injuries from contact with other birds. Intuitively, it is reasonable to assume that the likelihood of such adverse consequences would increase as the space available per bird decreases.

The importance of stocking density to the maintenance of good animal welfare is reflected in animal welfare legislation in many countries. For example, in Australia, densities are restricted to a maximum of 40 kg/m2 in intensive production systems (PIMC, 2002) and in the European Union, a maximum of 42 kg/m2 is permitted (European Commission, 2007). Notably, the highest densities are permitted only if specific welfare outcomes (e.g. maximum mortality rates, European Union legislation) or specific ventilation/seasonal/geographic requirements (Australia) are met. Such variation in permissible stocking densities reflects policy-makers' and scientists' views that stocking density alone does not determine welfare outcomes. A large number of variables, in addition to ambient conditions, may take precedence over or interact with density to influence welfare, including strain of bird, litter type, quality of management, lighting and feeding schedules (de Jong *et al*., 2012a).

A large number of scientific studies examining the effects of stocking density on bird welfare have been conducted in laboratory settings, but few have been researched in commercial production environments (for example, see the recent review by de Jong *et al*. (2012a)). However, a causal link between stocking density and chicken welfare is far from clear, as many contradictory results have been reported across the studies. An exception to this is a reasonably consistent increase in behavioural disturbance, or associated conditions (such as scratches to the body), with increases in stocking density (de Jong *et al*., 2012a; Ventura et al. 2012).

Key reasons for the inconsistencies are likely attributable to:

- Major differences between studies in broad experimental approaches and settings; and
- Differences in environmental and bird management (such as lighting schedules, litter quality, feed quality, density ranges).

In regards to the influence of experimental approach and setting, intensive commercial chicken meat production systems require the optimisation of a large number of animal, dietary, environmental and management variables to ensure high welfare standards (Wilson, 2008). All these factors interact to influence productivity and welfare outcomes. Given that experimental studies are usually conducted in specially-designed, laboratory settings and with limited resources, it is extremely difficult, if not impossible, to replicate commercial conditions (e.g. group size) in the laboratory. Further, laboratory studies are almost always conducted in settings where the environmental conditions cannot be optimised for each individual treatment (e.g. stocking density). Thus, key parameters that are implicated in stocking density effects are not usually controlled in laboratory studies, and may therefore not replicate commercial conditions. Other important factors that often differ between commercial and laboratory research settings include the layout of feeding and watering facilities, ratio of wall space to non-wall space and litter management procedures (Buijs *et al*., 2011a).

One method to overcome the limitations of typical laboratory studies is to conduct experiments in commercial production houses. To our knowledge, only one study of stocking density using experimental methodologies in production settings was conducted in the UK and Denmark. Several papers have been published from this study (Dawkins, *et al*., 2004; Jones *et al*., 2005; Febrer *et al*., 2006) and provide data on the effects of stocking density on common health and welfare/behavioural measures, environmental parameters and bird productivity.

Other studies have been conducted in commercial production units that have used an epidemiological (as opposed to experimental) methodology. Epidemiological research has the advantage of being commercially-relevant, and can identify associations between management variables and bird welfare. Several examples of this type of research have been carried out in Europe, including a 2006 study conducted across four European countries (Bassler *et al*., 2013) and another that was conducted in New Zealand (Bagshaw *et al*., 2006). A key limitation epidemiological studies is that it cannot establish cause-and-effect relationships between management or other variables and bird welfare.

In regards to the differences in the environment and bird management, many factors have not been standardised across studies. These include the range of densities investigated, the methods for calculating density, group and pen sizes, strain of bird, and degree of control over environmental conditions (de Jong *et al*., 2012a). As an example of differences in the quality of bird management between studies, Allain *et al*. (2009) reported that most of the birds (71%) had severe foot lesions, whereas in the Dawkins *et al*. (2004) experiment, only 3% of birds had severe lesions, even though densities covered a similar range in both (Allain *et al*., 28 to 46 kg/m2; Dawkins *et al*., 30 to 46 kg/m2). It would seem that litter quality differed markedly between studies, with much higher quality in the Dawkins *et al*. (2004) work. Thus, a comparison between studies would be confounded by differences in litter condition.

Several studies using the epidemiological methodology have been conducted in recent years. The research conducted by Bassler *et al*. (2013) covered the most countries and used data collected on commercial farms in Italy, the Netherlands, France and the UK. The mean stocking density was 31 kg/m2 (with a range of 18 to 48 kg/m2 for the 5th and 95th percentiles, respectively). Stocking density was not identified as a risk factor for any welfare parameters measured (walking ability, FPD, HB and fear of humans). Similarly, an epidemiological study in France (Allain *et al*., 2009) found no relationship between stocking density and FPD, but breast blisters and scratches on the body were elevated at higher densities. In New Zealand, an epidemiological study revealed the absence of associations between stocking density (range 33 to 39 kg/m2) and all welfare measures recorded (walking ability, FPD, HB, breast blisters and mortalities) (Bagshaw *et al*., 2006). In Denmark, Kyvsgaard *et al*. (2013) showed that FPD increased in summer and decreased in the winter at densities above 40 kg/m2 and that litter quality was not related to density. For UK flocks, Hepworth *et al*. (2010) showed that density had no effect on HB prevalence and Knowles *et al*. (2008) showed that walking ability declined slightly with increases in density (e.g. a 10 kg/m2 increase in density corresponded to a 0.13 decrease in walking ability on a 6 point scale). The results from these epidemiological studies support the findings from the experimental study by Dawkins *et al*. (2004), which reported no effect of stocking density on FPD and HB or impaired walking ability or mortalities. Although the same study found that the prevalence of good walking ability declined at the highest targeted density (46 kg/m2) and growth rate declined at the highest targeted density (46 kg/m2), but not actual density. Density had no effect on faecal corticosteroid concentrations (a measure of stress). Litter quality was poorer (wetter) at higher target densities, but not actual stocking densities. Epidemiological study also revealed increased 'jostling' at densities of 42 and 46 kg/m2 (Febrer *et al*., 2006).

Taken together, these studies indicate that under commercial conditions, stocking density has little effect on several key welfare indicators (mortality, walking ability, skin conditions, jostling) at the densities used in Australia. The absence of an effect of stocking density on mortality and an increase in behavioural disturbance at higher densities have been replicated in laboratory-based studies, although disturbance effects are reported to begin at lower densities in the laboratory (e.g. Ventura *et al*., 2012). The reasons for the effect at lower densities in the laboratory are not clear and further replication in commercial production systems is required.

In contrast, results obtained in the laboratory have provided a large amount of contradictory information on the impacts of stocking density on variables such as growth rates, feed intake, leg pathologies (walking ability and skin conditions), measures of physiological stress and fear, and time budgets for major activities (see review de Jong *et al*., 2012a). Laboratory studies published since the review by de Jong *et al*. (2012a), for example, Buijs *et al*. (2012) and Houshmand *et al*. (2012), show that these inconsistencies remain unresolved.

A possible explanation for the large variation between laboratory studies is that factors other than stocking density have a major influence on welfare outcomes, and these variables differ between studies. Jones *et al*. (2005) and Dawkins *et al*. (2004) demonstrated that environmental parameters, such as time spent outside the recommended humidity range in early life and in the last days of rearing were much more influential than stocking density on welfare measures under commercial conditions. Further, they showed that stocking density had little impact on temperature and humidity levels in the rearing sheds.

An issue that has been reported at high densities, and which is logically connected to behavioural disturbance, is the amount of space that a bird would prefer to have available for its activities. Under commercial conditions, Febrer *et al*. (2006), using a modelling procedure, showed that close proximity to other birds was not aversive, as birds clustered more than would be expected from a random distribution. Other studies conducted in laboratory settings have reported that, even at relatively low densities (15 kg/m2), birds avoid each other (Buijs *et al*., 2011a). Further, Buijs *et al*. (2011b) has shown that birds kept at 40 kg/m2 showed a strong motivation to move to an area of lower density (23 or 32 kg/m2). Measures of the physical space requirements of birds indicate that they are compressed at densities above 40 kg/m2 (Bokkers *et al*., 2011). It would be worthwhile to replicate studies on motivation for space in commercial houses to test the generalisability of these findings.

To summarise, and as also noted by de Jong *et al*. (2012a), a clear threshold for stocking density to maintain good welfare has not yet been determined and additional research conducted under commercially relevant conditions is required to determine acceptable upper limits. Most of the commercially relevant information on stocking density is derived from a single experimental study and a limited number of epidemiological evaluations conducted in Europe (e.g. Dawkins *et al*. (2004). No similar research has been published for chickens grown in Australia, yet the UK research, and indeed Australian Model Code of Practice (PIMC, 2002) for meat chickens, explicitly recognises the pre-eminence of local environmental conditions (in combination with high stocking density) in determining bird welfare. Thus, it is highly desirable that this work be replicated in Australian production houses and expanded to include a wider range of stocking densities (less than 30 kg/m2). It would also be helpful to examine the potential benefits of barrier perches (Ventura *et al*., 2012) for reducing behavioural disturbance at higher densities in commercial production systems. Scratches to the body (or other novel measures) deserve investigation as a practical way to assess potential adverse impacts of high stocking densities.

4. Meat chicken breeder feeding

Genetic selection for increased growth and improved feed efficiency has resulted in a high feed intake in meat chicken breeders. Consequently, the *ad libitum* feeding of meat chicken breeders during rearing leads to high body weight prior to laying, which may result in poor health (Heck *et al*., 2004; Dawkins and Layton, 2012) and reproductive concerns (Hocking *et al*., 2002; Mench, 2002). Hence, the feed intake of meat chicken breeders is routinely controlled during rearing to prevent health and reproduction problems at a later age (Savory *et al*., 1993; De Jong and Jones, 2006). Meat chicken breeders are typically fed between 25-50% of their *ad libitum* voluntary feed intake (Savory *et al*., 1993), usually using a set program with target weights at particular ages, in order to maintain their body weight within a narrow range optimal for reproduction and health. Despite the fact that growth rate and body size have drastically increased through genetic selection, the underlying normal controls of feeding behaviour are conserved in meat chicken breeders (Howie *et al*., 2009). Consequently, controlled feeding can be a welfare concern if it results in chronic hunger or other negative affective states, such as frustration, redirected behaviours (e.g. aggression, polydipsia), abnormal behaviours or high levels of competition around feeding times (see D'Eath *et al*., (2009) Table 1 for a summary of findings). The industry currently employs a range of different feeding regimens, which differ in the frequency of feeding, quantity or type of feed delivered. The most common method for feeding meat chicken breeders in Australia is skip-a-day feeding, whereas everyday feeding is more frequently employed in other parts of the world. Few studies have compared skip-a-day versus everyday feeding methods, but recent evident suggest that there is little difference in terms of bird welfare (Morrissey *et al*., 2014), which therefore does not support the decision of some European Union countries to ban skip-a-day feeding on welfare grounds. Although controlled feeding ensures long-term welfare, the short-term welfare of meat chicken breeders is impaired during feed intake control (Hocking *et al*., 1993, 1996; Savory *et al*., 1993, 1996; Mench, 2002). Feed-controlled meat chicken breeders display redirected behaviours purportedly indicative of hunger and frustration, such as pecking at non-food objects, increased activity, aggression and feather pecking, or polydipsia (Hocking *et al*., 1996, 2001; De Jong *et al*., 2002; Sandilands *et al*., 2006). Operant feeding tests indicate that feed-controlled meat chicken breeders have a high motivation to eat (Savory *et al*., 1996; De Jong *et al*., 2003). Nevertheless, preference or motivation tests have returned inconclusive results, because the state of feed-restricted birds affects motivation, stress, learning or memory (Buckley *et al*., 2011a,b; Dixon *et al*., 2013). However, a new testing paradigm using water crossing appears promising (Dixon *et al*., 2014). Additionally, indicators of chronic stress (e.g. increased plasma corticosterone concentrations and heterophil : lymphocyte ratio) are reported in feed-controlled meat chicken breeders (Hocking *et al*., 1993, 1996; De Jong *et al*., 2002; Savory *et al*., 1993), but reliable physiological indicators of feeding motivation and/or satiety still require further research (de Jong *et al*., 2003, 2005a). Furthermore, the psychological welfare implications of controlled feeding remain to be elucidated (D'Eath *et al*., 2009). Whether habituation or adaptation to different programs of quantitative restriction can occur is not clear (Hocking and Jones, 2006; Morrissey *et al*., 2014; Mench, 1991) and requires further research.

Alternative feeding strategies aimed to maintain body weight control while improving welfare, focusing on diet dilution (e.g. qualitative dietary restriction), appetite suppressants (e.g. calciumpropionate, oat or soybean hulls) or altering dietary protein levels, do not clearly benefit meat chicken breeder welfare (De Jong *et al*., 2005a; Hocking, 2006; Savory *et al*., 1996; Savory and Lariviere, 2000; Morrissey *et al*., 2014; Sandilands *et al*., 2006; van Emous *et al*., 2014). However, evidence suggests that hunger-related behaviours can be attenuated by insoluble but not soluble fibres, with soluble fibres causing digestive discomfort, high water consumption and consequently litter management issues (Nielsen *et al*., 2011). Similarly, environmental enrichment strategies, such as scattered feeding in the litter, splitting the feed in two rations daily (De Jong *et al*., 2005b), or providing bales of wood shaving and strings (Hockings and Jones, 2006) have been reported to have little effect on bird welfare.

Genetic selection to reduce the need for controlled feeding (Dawkins and Layton, 2012) or the use of dwarf meat chicken breeders (a recessive sex-linked gene for females (Jones *et al*., 2004)) have been suggested as solutions for the future. Indeed, while growth potential in meat chickens has increased significantly in the last 30 years, controlled feeding programs have increased relatively little, resulting in an increasing degree of feed restriction in meat chicken breeders (Renema *et al*., 2007). Furthermore, recent findings show that the effects from feeding restriction on meat chicken parents can affect their progeny's welfare, with higher incidence of FPD in meat chickens from parents fed on skip-a-day, compared to everyday feeding when combined with thermal stress during incubation (Da Costa *et al*., 2014).

In summary, while controlled feeding practices for meat chicken breeders prevent the development of health and reproduction problems during the laying stage, and therefore ensure long-term welfare, the short-term welfare of meat chicken breeders may be impaired during severe feed intake control, especially in the rearing stage. A number of controlled feeding regimens are used by the chicken meat industry, which differ in the frequency, quantity or type of food delivered. The welfare implications of the different feeding regimens for meat chicken breeders have yet to be fully examined, and there is currently no strong scientific evidence for favouring the everyday feeding method over skip-a-day feeding methods. Progress may be achieved through the identification and use of animal-based measures related to feeding behaviour and satiety, nutritional manipulation and genetic selection (for review, see Van Krimpen and de Jong, 2014).

5. Thinning

Thinning refers to the partial depopulation of a flock during rearing, usually to meet market requirements for particular sized birds. It is a common practice in many European countries (Bassler *et al*., 2013), New Zealand and Australia. To our knowledge, there have been no formal experiments on the effect of thinning on chicken welfare. However, several epidemiological investigations, and one experimental study with commercial flocks, have looked for associations between thinning practices and some welfare measures. There are some major scientific limitations to this type of research and so it is not possible to ascribe cause-and-effect from epidemiological studies. Comparisons of birds before and after thinning are typically inextricably confounded with age and stocking density, as the birds remaining after thinning are older and maintained at lower densities. Further, there may be other unknown, systematic differences between thinned and non-thinned flocks.

Jones *et al*. (2005) reported that thinning of UK and Danish flocks was not associated with any welfare measure (walking ability, FPD or HB) or with variation in environmental parameters (temperature, humidity, litter moisture or ammonia concentrations). Similarly, Allain *et al*. (2009), using flocks in France where one-third had been thinned, found no significant correlations between thinning and various skin conditions (FPD, HB, breast blisters) or injuries due to scratches, and Manning *et al*. (2007a) reported that prevalence of FPD was correlated in thinned and non-thinned birds at slaughter in UK flocks.

Using Dutch flocks, de Jong *et al*. (2012b) noted that thinned birds had lower FPD than birds of an equivalent age that originated from flocks in sheds that were completely depopulated in a single lot. They speculated that birds coming from non-thinned flocks might have been stocked at higher densities. Further, de Jong *et al*. (2012b) noted that FPD was lower in birds that remained after thinning (compared with birds in flocks that had not previously been thinned), and considered that the lower density of thinned flocks may explain the decrease in thinned flocks. Haslam *et al*. (2007) considered that thinning may lead to improvements in FPD due to improved litter quality or healing of lesions, but no data were provided. In an epidemiological study of UK flocks (with two-thirds thinned), Knowles *et al*. (2008), found that walking ability declined by 0.25 of a score (on a 6-point scale) after thinning, than would be expected for birds of their age. They considered that the decline in walking ability may have related to the (putative) stress of thinning, or perhaps that proportionately more of the larger and faster growing males (which would have poorer gait than a mixed sex flock) remained after thinning.

Thus, thinning has been associated with improvements, declines and no change in welfare status. Further research using controlled experimental studies is required before significant statements can be made regarding the welfare impacts of thinning.

6. Light

As diurnal animals, lighting characteristics can undoubtedly influence chicken behaviour and physiology, with associated effects on their welfare and productivity (for review, see Olanrewaju *et al*., 2006). The Australian Model Code of Practice (PIMC, 2002) states that "young birds reared away from the hen require a light intensity of about 20 lux on the food and water for the first three days after hatching in order to learn to find food and water". It may then be reduced to as low as 2 lux during rearing (Item 5.1, PIMC, 2002). Other schemes have different specifications for light requirements, such as the RSPCA Australia approved farming scheme standards (items 1.15 and 3.23-3.25, RSPCA Australia, 2013).

Light exposure is a complex topic because it includes several characteristics: photoperiod, light intensity, wavelength and light source, which can have main or interactive effects. Furthermore, while the effects of light exposure on productivity have been well studied, less research has focused on its effects on behaviour and welfare (apart from feed intake).

Photoperiod: length and distribution

Longer photoperiods, up to constant or near-constant light (e.g. 23L:1D, meaning 23 hours of light (L) and 1 hour of darkness (D)), have been commonly assumed to provide more time for feeding and subsequently lead to higher body weight. Schwean-Lardner *et al*. (2012a) have compared 14L, 17L, 20L and 23L within a single experiment and found that 20 L gave the higher live weight at 38.5 days of age, and 17L and 20 L obtained similar live weight for birds grown to heavier weights of 48.5 days of age. Shorter photoperiod (14L and 17L), however, resulted in a linear improvement in feed efficiency, better gait score, lower foot pad lesions at 28 and 35 days of age (but not at 45 days), and lower mortality, mostly of metabolic or skeletal origins (Schwean-Lardner *et al*., 2013). However, Brown (2010) reported no effect of longer dark periods on walking ability. This reduction in early growth associated with longer dark periods is assumed to be responsible for better feed conversion efficiency, lower mortality (mostly SDS and ascites) but also lower condemnations, with the birds showing compensatory growth and similar final body weight (Classen, 2004, comparing 12L, 16L and 20L).

In terms of behavioural changes, birds under 14L and 17L spent more time at the feeder than under 20L and 23L regimes, while resting time increased and walking time and comfort behaviours, such as dustbathing and preening, decreased with longer (20L and 23L) photoperiods (Schwean-Lardner *et al*., 2012b). However, birds under 14L were observed feeding and preening at night, likely to compensate for the reduced time available during light periods (Schwean-Lardner *et al*., 2012b), and activity at night with short (12L) photoperiod has been report by others (e.g. Brown, 2010; Lewis *et al*., 2009). Hence, birds kept under 14L and 17L regimes appeared to have a richer behavioural repertoire than birds under 20L and 23L regimes, with counterintuitively more daylight time available for activity, and according to the authors' calculation, 16L would lead to the best welfare outcomes in their settings (Schwean-Lardner *et al*., 2012b).

Birds under 23L are reported to have heavier and larger eyes than birds under 20L (Schwean-Lardner *et al*. 2014; Lewis and Gous, 2009a), but birds kept under shorter photoperiod also have larger (Blatchford *et al*., 2012 for 16L) or heavier eyes (Lewis and Gous, 2009a, from 18L to 2L) than birds kept under 20L. These findings altogether suggest a U-shaped response of shorter or longer photoperiod on eye morphology, however, it is unclear how much these reflect changes in the birds vision. Birds kept under 23L also showed a lower amplitude of melatonin (a hormone controlling the circadian rhythm) and with secretion peaking during darkness, which may be linked to the asynchronous flock behaviour observed in birds under near-constant light (Schwean-Lardner *et al*.

2014). Melatonin has also been shown to regulate immunity, hence possibly underlying the effects of various photoperiods on health (Kliger *et al*., 2000).

In addition to the 24h photoperiod length, the distribution of the light cycle may be important but has received comparatively little attention. Classen *et al*. (2004), comparing 12L:12D, 6L:6D and 1L:1D within 24 hours, reported lower mortality with longer cycles and lower growth rates, but better uniformity, gait score and feed efficiency, either due to lower metabolic rate or reduced early growth. Duve *et al*. (2011) found that chickens can adapt their feeding behaviour between a continuous 8D or two equally space 4D, but this study did not investigate other behavioural or welfare changes apart from reporting no effect on the incidence of FPD.

Interpretation of the literature on the effects of photoperiod is further complicated by the practice of step-down and step-up programs, which consist in raising or decreasing light regimens at various stages of production (Downs *et al*., 2006). Such programs do not appear to be currently commonly used in Australia and have received little scientific attention. Some effects of photoperiod on welfare may also be indirectly attributable to alterations in growth pattern rather than the effect of behavioural and physiological effects of light per se. Lighting is not the only way to achieve welfare benefits from reduced growth rates as patterning of feeding times and quality of feed offered can achieve the same results (e.g. Bizeray *et al*., 2002c).

Light intensity

While there is a substantial amount of literature on the effects of light intensity on production variables, relatively few studies examined the effects of light intensity on behaviour and welfare. Furthermore, some studies restricted their behavioural observations to light periods (e.g. Kristensen *et al*., 2007), which may not be representative of overall daily behaviour because, as noted earlier, birds may also modify their activity during the dark phase. In one of the few studies that directly compared light intensity and photoperiod on behaviour and welfare, Blatchford *et al*. (2012) concluded that light intensity during the day (1 vs. 200 lux) had a much larger effect compared to photoperiod (20L versus 16L). However, this effect may have been caused by the low illumination contrast between their light and dark phases, rather than the light intensity itself. Multiple authors (Alvino *et al*., 2009a, b; Blatchford *et al*., 2009, 2012) reported that birds kept under 1 or 5 lux showed a less pronounced circadian rhythm, with active (eat, drink, walk and forage) and inactive behaviours dispersed throughout the light and dark cycles, as opposed to birds under 50 or 200 lux, which showed a more clear-cut circadian patterns (active and feeding during daylight and less active at night). However, they provided 0.5 (Blatchford *et al*., 2012) to 1 lux (Alvino *et al*., 2009a; Blatchford *et al*., 2009) of light during the dark period (i.e. scotophase). The authors have noted that this light contrast may possibly be too small to induce a day-night cycle with the birds not being able to distinguish easily between photophase and scotophase, because Deep *et al*. (2012) observed a circadian behavioural and melatonin concentration rhythm when birds were reared with a 1 lux photophase and 0 lux scotophase. Nevertheless, this series of studies was useful in demonstrating that a sufficient light intensity contrast is important for the birds to maintain a circadian rhythm, and therefore that a low light intensity during the scotophase is also important. A higher light contrast (200 lux photophase and 1 lux scotophase) resulted in a greater degree of behavioural synchrony in a flock than lower contrasts (5 lux photophase and 1 lux scotophase), with 50 lux being intermediate (Alvino *et al*., 2009b). The welfare outcome of behavioural synchrony in a flock may be conflicting, because better behavioural synchronisation increased uninterrupted resting behaviour during the dark phase (Alvino *et al*., 2009b), but conversely could theoretically result in increased competition for access to resources during the light phase. Alvino *et al*. (2009b) did not report such effects when offering feeder space for 20% of the birds at any one time with groups of 35-42 birds. This hypothesis remains to be tested in commercially-relevant conditions, as Wilson and Bourne (2011) have reported field evidence that long dark periods can increase competition at feeders with a resultant increase in scratching of the skin, whereas Classen (2004) actually found a 12L photoperiod resulted in lower condemnations than 16L and 20L, mostly from cellulitis assumed to originate from scratches.

Deep *et al*. (2013) concluded that 0.1 lux is an unacceptably low light intensity, returning 3.3% mortality within the second week after abruptly changing the birds from their first 7 days at 40 lux, whereas keeping birds under 0.5 to 10 lux had little effect on mortality (ranging from 1 to 2% in that same week, but the following experiment returned more normal values of 2.1 to 2.5% mortality from 0 to 35 days of age). Birds kept under 0.5 and 1 lux had more severe footpad lesions and heavier and larger eyes than birds kept under 5 and 10 lux, whereas 5 and 10 lux returned similar values (Deep *et al*., 2013). Light intensities lower than 5 lux are well-recognised to cause retinal degeneration, eye enlargement, myopia, glaucoma and blindness (Olanrewaju *et al*., 2006). Other studies confirmed that birds kept under 1 lux have both larger and heavier eyes (Deep *et al*. (2010) comparing 1, 10, 20, or 40 lux; Blatchford *et al*. (2012) comparing 1 to 200 lux). Blatchford *et al*. (2009) also found that birds kept under 5 lux had heavier eyes than birds kept under 50 or 200 lux. It is not possible to determine if the discrepancy between eye weight difference observed by Blatchford *et al.* (2009) (comparing 5 to 50 and 200 lux) and Deep *et al.* (2013), comparing in the range of 0.5 to 10 lux, is due to the scotophase of 1 lux used by Blatchford *et al*. (2009), or the difference in the range of comparison studied. Nonetheless, Blatchford *et al*. (2009) found no effect of 5 lux on eye diameter or the corneal radii that have been reported under lower intensities such as by Deep *et al*. (2013). The welfare implications of these changes for birds vision are still unclear.

The determination of an optimal light intensity for chicken welfare is further complicated by the fact that meat chickens seem to have different preferences at different ages; 2 week old meat chickens were found to prefer the brightest treatment of 200 lux, whereas 6 weeks old meat chickens preferred the dimmest treatment of 6 lux (Davis *et al*., 1999). This may correspond to the increased level of inactivity in older birds, which prefer dim lights (Newberry *et al*., 1985). However, these findings appear to invalidate recommendations that a minimum of 20 lux should be provided at all ages (Farm Animal Welfare Committee, 1992).

In general, as the day-night light intensity contrast increases, birds spend more time active, foraging and preening during the photophase and more time resting during the scotophase, although birds kept under low light intensity are found to rest more over the course of the day. Despite Olanrewaju *et al*. (2006) reporting that, in uncited field studies, intensities above 5 lux reduce body weight through increased activity, the hypothesis that light intensity decreases weight gain through increased activity does not appear to have been formally tested (e.g. Downs *et al*. (2006) studying 20 lux vs. a decreasing program from 5.4 to 2.7 lux starting from week 2). Furthermore, recent studies report little effect of light intensity in the range of 1 to 200 lux on time spend walking (Deep *et al*. 2012; Alvino *et al*., 2009a), and effects on body weight gain are generally small (e.g. Deep *et al*., 2013; Downs *et al*. 2006).

A major limitation is that all these studies were conducted in research settings which may or may not reflect commercial conditions in terms of group size, stocking density and other management variables. Hence, it is difficult to assess the welfare implications of behavioural changes induced by varying light programs on common meat chicken welfare criteria such as mortality, gait scores and leg health, FPD, HB and scratches on the body. Further research is required to determine the acceptable minimum level of light intensity in accordance with the effects of the contrast between scotophase and photophase.

Light source

Chickens have trichromatic vision and can discriminate colours. For instance, increasing red light (415 nm peak) has been reported to stimulate activity in meat chickens, while varying blue light (635 nm peak) wavelengths had little effect on activity but resulted in poor gait scores (Prayitno *et al*., 1997a). Nonetheless, birds given the choice prefer blue or green light over red or white (Prayitno *et al*., 1997b).

A variety of light sources are now on the market, such as incandescent (slowly being phased out), fluorescent and the most recent LED light sources. A review from Lewis and Morris (1998) concluded that fluorescent and incandescent lights provided for similar welfare outcomes. The widespread adoption by industry of LED light requires evaluation for their welfare implications. The fact that some LED light may emit UV light may affect poultry which, unlike humans, have a fourth retinal cone that allows them to see in the UVA part of ultraviolet radiation (Prescott and Wathes, 1999). However, it has been suggested to be of little beneficial impact on birds provided their diet contains adequate levels of vitamins D_3 (for review, see Lewis and Gous, 2009b).

Another source of light is natural sunlight, but its effects on meat chicken behaviour and welfare has not been significantly researched, even though is has relevance to free range systems and houses with clear curtains and open sided walls. The light intensity of natural light on a sunny day may be as high as 100,000 lux (Thery (2001) as cited in Kristensen *et al*., 2007), and it also provides UV radiation, which is not necessarily emitted by all types of artificial light sources. The provision of natural light has been shown to increase activity, although only behaviour was analysed for the mid-day period, and improved leg conditions (Bailie *et al*., 2013). However EFSA (2010a) cautions the possibility of increased scratches in birds kept under natural light, although credible sources were not cited. Finally, no recent studies could be found on the welfare advantages of providing progressive light program transitions at dawn and dusk, apart from empirical observations that birds appear more distressed with abrupt light changes, especially with a large contrast. Whether chickens habituate to abrupt light changes has not been investigated.

7. Environmental enrichment

Criticism of conventional meat chicken production often emphasises its ‘barren’ housing environment, with the lack of stimulation or resources for birds to perform natural behaviours, such as perching, foraging and dust-bathing. The barren environment is also hypothesised to lead to boredom (EFSA, 2010a). EFSA (2012; p.3) concluded that “there are currently no animal-based measures to use as welfare outcome indicators on-farm to assess the issues of pain, frustration, boredom and other positive and negative emotional states in the standard broiler”. Environmental enrichment can be defined as “an improvement in the biological functioning of captive animals resulting from modifications to their environment” (Newberry, 1995). The advantage of this definition compared to others is that it encompasses not only the modification itself, but also the necessary functionality of providing environmental enrichment. The standards of some certification programs require the provision of environmental enrichment. For example, RSPCA Australia’s Approved Farming Scheme program requires that, “Environmental enrichment must be provided inside the shed for all birds in the form of both perching and manipulable material from at least 7 days of age” (item 3.26; RSPCA (2013)), without being descriptive on what qualifies as enrichment. Environmental enrichment for chickens can come in many shapes or forms, such as the provision of physical items (e.g. infant toys, mirrors, balls, tubing, beads, strings and rubbers; most often items which birds can peck, but also perches or partitions), natural items (e.g. straw bales, balls of wood-shavings, litter, scattering of whole grains), but also the provision of windows or an outdoor range (for a list of attempted enrichment items for poultry, see Jones, 1996). Nevertheless, in many instances, the functional relevance and welfare benefits derived from the provision of environmental enrichment remains to be scientifically and rigorously demonstrated (for review, see Newberry, 1995). Environmental enrichment is a complex topic with implementations that can either result in beneficial, null or even detrimental effects on animal welfare (Wurbel and Garner, 2007). Parameters such as the time at which an enrichment program is implemented, the design of the devices provided, or its biological significance can determine the success of the program. Newberry (1995) warns against the assumption that the investigation or use of enrichment devices by the animal unconditionally results in improved welfare in the long-term. In fact, few studies have investigated the effects of providing enrichment for meat chickens for both the behavioural changes and long-term welfare consequences.

Raising meat chicken in more complex environments can stimulate exploratory behaviours and reduce fear responses to sudden or unpredictable events, as has been demonstrated in experimental settings (Jones and Waddington, 1992; Newberry, 1999). This can, in turn, result in practical benefits such as chickens being more resilient to handling or transport stress (Zulkifli *et al*., 2002; Nicol, 1992). Nonetheless, these principles can be more difficult to implement in commercial conditions due to the multitude of interactive factors (Newberry and Estevez, 1997). For instance, panels can reduce disturbances to other birds, increasing resting time (Cornetto and Estevez, 2001a, b), and improve distribution of the birds by increasing the number of birds using the centre and away from the edges (Cornetto and Estevez, 2001b; Ventura *et al*., 2012). However, these experiments were conducted in small pens of 80-140 birds, and require replication in typical commercial settings.

The provision of litter, which is common practice in rearing meat chicken chickens in Australia, can be considered a form of enrichment, with chickens being more attracted to sand substrate over paper and wood-shavings, and showing no attraction to rice hulls (Shields *et al*., 2004). Although this study focused on dust-bathing, the authors interpreted this choice to be based on the motivation of birds to explore and forage, but also presumably ingest sand. The authors hypothesised that although meat chickens do not need grit to help digest commercially prepared rations, they may have retained a motivation for seeking it. Nevertheless, despite their long-lasting interest in sand over wood shavings (Arnould *et al*., 2004), meat chickens performed the same behavioural repertoire on sand or wood-shavings (Shields *et al*., 2005), which is beneficial as wood shavings are the most common bedding substrate used in Australia. Shields *et al*. (2004, 2005) did not investigate the effects of spending time in the sand versus other substrates on welfare variables other than behavioural changes, albeit litter substrate is well known to affect leg and foot conditions through its different characteristics (see section 2. Leg and foot conditions). Arnould *et al*. (2004) did not find any effect of providing sand substrate on bone quality or tarsal angulations, but in this study, only a few small trays of sand were offered.

Bizeray *et al*. (2002a, b) tested the effects of providing 15cm high, 1m long barriers between feeder and drinker lines, a coloured moving spot light, or whole grain scattered on the floor in experimental settings. Although the intent of the barrier was to increase exercise, it did not affect walking time as birds passed over them rather that around them. Further, birds provided with the barriers altered their feeding pattern by less frequent visits to feeders and drinkers, likely due to the additional effort required to navigate between the two resources (Bizeray *et al*., 2002a). The birds also spent 10% of their time perching on the barriers, suggesting that the barriers actually served as perches rather than as their initially intended function of physical barriers. Moving spotlights only increased feeding and scattering whole grains on the floor had no effect on behaviour (Bizeray *et al*., 2002a), but both treatments actually resulted in the worse gait scores (Bizeray *et al*., 2002b), hence reduced welfare. These studies found no effects of providing barriers, spotlights or scattering grains on bone quality or tonic immobility (an indicator of fear response), and overall highlighted that behavioural changes may not necessarily equate to better welfare consequences (Bizeray *et al*., 2002a, b).

Perches are often cited as a potential solution to improve leg health through physical exercise. However, the use and effects of perches may depend on factors such as the design, height of the perch from the floor, location within the shed, time at which they are provided or the age of the birds (Oester and Wiedmer, 2005; Estevez *et al*., 2002). For instance, difficulties in getting on or off the perch, especially as birds get heavier, may result in low use and consequently nil effects on welfare (LeVan *et al*., 2000; Pettit-Riley and Estevez, 2001). Furthermore, the provision of enrichment can sometimes induce aggression, either around competition for the resource, or because of the behavioural changes that this enrichment resource induces, such as sudden movements moving to or from perches, which can trigger an aggressive reaction from conspecifics (Pettit-Riley *et al*., 2002). Alternatively, barrier perches were found to reduce aggression and disturbance, and particularly were found to overcome the effects of higher disturbance at higher stocking densities (Ventura *et al*., 2012; comparing 8, 13 and 18 birds per sq. m), although the maximum experimental group size was 90 birds per pen with social and spatial dynamics possibly not representative of commercial conditions. Theoretically, perching could also create benefits by reducing the amount of time birds spend in contact with the floor and, therefore, lowering the incidence of FPD, HB or breast blisters. Perch use has been reported to peak around 4 to 5 weeks of age (Hongchao *et al*., 2014; Ventura *et al*., 2012; Bizeray *et al*., 2002a; Estevez *et al*., 2002; LeVan *et al*., 2000), which corresponds to the late stage of production when risks are higher. However, these studies reported no effects of providing perches on foot or leg conditions, possibly because the duration of use such as those reported in these studies (5-10% maximum) was generally too low to be beneficial, or because other factors, such as growth rate, may have a more significant impact. Interestingly, the provision of 10º C water-cooled perches can enhance the ability to cope with heat stress (Reilly *et al*., 1991; challenging birds at 32.6 ºC from weeks 3 to 7). Chickens also increase their use of water-cooled perches (and, to a lower extent, higher perches of 15cm vs. 7.5 cm from the floor) from day 21 to day 43 (Estevez *et al*., 2002), especially females, which correspond to the end of the rearing period when metabolic heat production increases. This example demonstrates that clear welfare benefits are possible from providing enrichment devices with specific functionality, to which birds respond appropriately. Nevertheless, small variations in enrichment design can have large consequences, by reducing the effectiveness of the enrichment or even making it detrimental to welfare. For instance, Ventura *et al*. (2010) reported that small barriers composed of three arms improved footpad conditions over a control, unenriched, treatment, but complex barriers in an E shape did not, which demonstrates the importance of proper design. Additionally, environmental enrichment items that, for example, reduce available floor space, such as horizontal perches, can potentially worsen welfare (Heckert *et al*., 2002).

Kells *et al*. (2001), using commercial flocks to study the RSPCA 'Freedom Food' enrichment scheme, found that straw bales were used by meat chickens and resulted in more activity and less resting and sitting around the bales and other parts of the house. This study also reported a higher mortality rate of 5.56% with bales compared to 4.25% without, and a higher culling rate of 0.83 vs. 0.42%, respectively, without reporting whether these were statistically significant differences. The reasons for higher mortality and culling were not reported, but raised the question as to which criteria is more important for behavioural repertoire, and mortality or culls for welfare assessment. Bailie *et al.* (2013), also using commercial flocks, observed minimal effects of proving straw bales on the activity and behaviours performed. However, they only observed behaviour at midday, the average use of the straw bales was not reported, and they provided 1 bale per 44m^2 vs. 1 bale per 17m^2 for Kells *et al*. (2001). Nevertheless, birds provided with straw bales had better leg health (assessed through gait score and latency-to-lie), but did not differ in terms of culls, mortality or final weight (Bailie *et al*., 2013).

Few studies have investigated the effectiveness of providing bunches of strings as enrichment to meat chickens and it is generally reported to be of little interest to them (Arnould *et al*., 2004), even though laying hens find them attractive and reduces feather pecking (McAdie *et al*., 2005). Familiar odorants have been shown to reduce fear of novelty in chicks in experimental settings (Jones *et al.*, 2002), but olfactory interventions do not seem to have been trialled on farm, despite the fact that chickens respond to olfactory cues (Jones and Roper, 1997). Other methods, such as visual human contact, could also be beneficial and practical (Zulkifli *et al*., 2002) because the meat chickens' fear of humans is found to account for 28% of the variation in FCE on a study of 22 commercial Australian farms (Hemsworth *et al*., 1994).

Environmental enrichment can benefit meat chicken breeder birds during the rearing period, by providing opportunities to learn to perch and navigate in 3D environments, but also by reducing floor eggs, disturbances, aggression and over-mating (for review on enrichment for meat chicken breeders, see Estevez, 2009).

Although environmental enrichment can potentially improve welfare, increasing the complexity of the environment often comes with higher management requirements and other associated problems. While one of the aims of enrichment is to stimulate bird activity by introducing novelty and sometimes changing environmental diversity, excessive or inappropriate enrichment can induce fear and stressful responses (Wemelsfelder and Birke, 1997; Bizeray *et al*., 2002b, with the latter study scattering whole grain on the floor caused a panic-like response). Furthermore, accidents with birds getting trapped or entangled in enrichment devices, ingesting pieces, hanging themselves or hurting themselves (e.g. bad landing from perches) can occur with inappropriately designed, placed or maintained enrichment programs. For instance, although compact disks appear attractive to the birds, they are prone to breaking overtime and dispersing in the litter. Birds can lose interest in an enrichment item overtime, which has been reported for meat breeders (e.g. Hocking and Jones, 2006, providing strings) and often require rotation of heterogeneous items, but such disinterest overtime has not been reported as an issue in meat chickens, possibly because of their short life or juvenile age and high exploratory drive. Biosecurity and health hazards, the use of organic sources of enrichment (e.g. straw), OHS, worker safety issues and costs have been overlooked by researchers, but constitute concerns that should be assessed prior to adoption by the industry. Nevertheless, carefully-designed and managed environmental enrichment may result in both improved bird welfare and higher productivity, as has been shown in one study with meat breeders (Leone and Estevez, 2008).

In conclusion, there is still limited evidence in the literature that the provision of perches strongly benefits meat chicken welfare. In general, perches appear to be poorly used, either because of their design, placement, the weight of meat chickens and other factors. Other enrichment strategies, such as the provision of straw bales or devices that birds can peck, have had variable success in terms of use by the birds, but the welfare benefits remain unclear. Nonetheless, environmental enrichment often aims at offering birds the ability to perform 'natural behaviours', which the field of animal welfare science is still experiencing difficulties to equate to clear welfare benefits based on biological functioning consequences or changes in affective states. Overall, the welfare implications of environmental enrichment programs requires further investigation in commercial settings, to account for the myriad of variables that influence on chicken behaviour and welfare.

8. Free range production

The use of the outdoor range by meat chickens is highly variable across farms, but also among flocks on the same farm (Dawkins *et al*., 2003; Jones *et al*., 2007). In a large study of 40 commercial flocks, Dawkins *et al*. (2003) found that the most relevant factors explaining ranging behaviour were the amount of tree cover, time of day and season. They obtained a maximum of 14.3% of the flock seen outside at any one time, but also mentioned that many birds used the range at dusk when it was not possible to count them. There is evidence that layer birds rotate throughout the day, with 75-80% of the flock accessing the outdoor at least every other day (Richards *et al*., 2011; Gebhardt-Henrich *et al*., 2014). However, outdoor range use may differ between layers and meat chickens, as meat chickens only have access to the outdoors for a few weeks from the time they are fully feathered to slaughter. Sunrise and sunset are recognised as favoured time by meat chickens to access the outdoor range (Nielsen *et al*., 2003; Dawkins *et al*., 2003; Jones *et al*., 2007). However, more data needs to be collected in Australian settings, as these studies were performed in Northern European summer conditions, whereas Australia has a much more temperate climate with milder and drier winter. Seasonal changes will strongly affect range use (Dawkins *et al*., 2003), with, for instance, 17.7% during summer and only 3.1% in UK winter (Jones et al., 2007). Birds are more prone to use the range if natural or artificial cover is provided (Dawkins *et al*., 2003; Jones *et al*., 2007). Trees, natural cover and artificial structures placed close to the shed can attract more birds in the range, but the maximum distance that they will cover between the shed and cover is yet to be determined (Mirabito and Lubac, 2001; Gordon *et al*., 2002). Nevertheless, birds are generally reluctant to venture more than 10 to 20 meters away from the shed, even when cover is provided (Mirabito *et al*., 2001; Dawkins *et al*., 2003; Rivera-Ferre *et al*., 2007). It is unknown whether this is the result of the increased effort or fear to venture in the range. However, it is well recognised that slow-growing strains range considerably more than fast-growing strain, which may be a consequence of genetic selection for lower activity or faster growth rates (Nielsen *et al*., 2003 comparing Ross 208 and Labresse cross; Dal Bosco *et al*., 2010 comparing Ross 308 and Ancona crossbred birds). In Australia, the overwhelming majority of meat chickens are fast-growing strains, whereas slow-growing strains are more common kept in free range systems in other parts of the world. Experimental studies attempting to keep fast-growing strains (e.g. Ross 208) from 6 up to 12 weeks of age have shown that this results in poor welfare outcomes due to the poor mobility and poor gait scores of those birds in later weeks (Nielsen *et al*., 2003), or high mortality mainly due to ascites (Castellini, 2002). Meat chickens perform a wider range of behaviours (e.g. preening, dust-bathing, exploration) when raised with an outdoor access, and especially more locomotory behaviours (Weeks *et al*., 1994; Zhao *et al*., 2014). However, this difference decreases over time, which Weeks *et al*. (1994) suggested is related to poor locomotion at later ages rather than a lack of motivation. However, access to an outdoor range does not seem to improve gait score (Weeks *et al*., 1994; Durali *et al*., 2014). A large epidemiological study reported higher prevalence of FPD in free range birds compared to indoor-reared, but these results could be confounded with breeds and diets (Pagazaurtundua and Warriss, 2006). Outdoor birds also performed more ground pecking (Weeks *et al*., 1994), and eat substantial amount of grass if given the opportunity, reported as 4% of their daily feed intake (Singh *et al*., 2013), with heavier gizzard weights (Durali *et al*. 2014). This diet energy dilution may explain the lower growth rates usually reported in free range birds (Weeks *et al*., 1994; Durali *et al*., 2012). Mortality has been reported to be approximately 2-3% higher in free range flocks (Weeks *et al*., 1994; Durali *et al*., 2012, 2013; Zhao *et al*., 2014), mostly due to yolk sac infection and sometimes predation (Durali *et al*., 2012). Free range birds in Australia do not get supplemented with in-feed antibiotics (e.g. anticlostridial enteritis) under the widely-adopted Free Range Egg Producers Association (FREPA) accreditation scheme (2009), which may be a cause for higher risks of infection rather than outdoor access. The direct effects of outdoor access on immunology and disease prevalence have been the subject of little scientific study, however, Permin *et al*. (1999) reported that free range birds have a higher prevalence of gastrointestinal helminths. Predation does not appear as an immediate concern, but is often more of a salient overestimated issue (Moberly *et al*., 2004). Feeding outside increases range use (Weeks *et al*., 1994), but brings biosecurity risks with wild birds, which in the case of highly pathogenic disease, such as avian influenza, creates serious welfare risks. Overall, little scientific research has been performed on individual birds in commercial flocks to better understand the welfare implications of using the outdoor range. The little amount of research that exists can also be contradictory, which further emphasises the need for more research in Australian local conditions, given the strong influence of weather conditions on the effects from ranging outside.

9. Welfare monitoring

Welfare monitoring is used for several different purposes, such as assessing compliance with legislation or policies of producer groups (e.g. integrated producer companies), food supply companies (e.g. fast-food chains or supermarkets) or welfare interest groups (e.g. NGOs).

Colditz *et al*. (2014), Main *et al*. (2014) and Butterworth *et al*. (2011) have summarised important generic factors that should be considered for monitoring schemes, although none of these papers focussed specifically on meat chickens. Berg and Algers (2004) and Algers and Berg (2001) have summarised key aspects of a meat chicken welfare monitoring system that has been successfully applied in Sweden and Barnett and Glatz (2004) have described a welfare auditing programme used in the Australian meat chicken industry.

The intended purpose of welfare monitoring will have an influence on key design features of an assessment methodology. Schemes designed to ensure continuous welfare improvement will incorporate aspects that ensure ready engagement by farmers, and timely and solution-orientated feedback, and may not require specific performance thresholds to be met (Buller *et al*., 2009 as cited by Butterworth *et al*., 2011; Colditz *et al*., 2014; Main *et al*., 2014; Main and Mullan, 2012). Farmer engagement can be encouraged by providing individual farmers with measures of their own performance, relative to that of other producers, to allow for benchmarking, ensures that the measures (and ideally improvements) can be carried out cost effectively and are fit-for-purpose (e.g. reliable and valid), and ensures that measures are used that do not inadvertently convey negative characteristics of welfare.

Timely feedback can be facilitated by using measures that are recorded, analysed and reported back regularly throughout the production cycle. Measures of the risks to welfare associated with the production facility, birds and management, together with an assessment of the welfare outcomes, provide the basis for action-orientated feedback. Measures of the resources available in the production environment provide the basis for risk assessment, and animal-based measures provide outcome-based procedures. Assessments linking risks with outcomes are consistent with the latest developments in scientific thinking and welfare management (EFSA, 2012). The Swedish system for assessing meat chicken welfare (Algers and Berg, 2001) is a good example of a scheme that incorporates feedback to farmers based on analyses of risk factors and welfare outcomes. For example, the surveillance programme identified a link between feed composition, litter quality and FPD, which led to better communication between producers and feed manufacturers regarding the cause of, and potential solutions, for the problem. In addition, the scheme developed an innovative mechanism to reward good welfare performance by permitting an increase in stocking densities (and, thus, profitability) for subsequent flocks (Algers and Berg, 2001). Foot pad monitoring took place in the slaughterhouse, hence the welfare of subsequent flocks (but not the monitored birds themselves) could be improved with this system. The surveillance programme was associated with a decline in FPD from 11% to 3% over the first three years (Berg and Algers, 2004). Interestingly, achieving continuous improvement does not necessarily require welfare thresholds, since individuals are motivated to improve their performance relative to others in the industry (Colditz *et al*., 2014).

The most comprehensive assessment protocol for meat chickens is the one developed by Welfare Quality® (Welfare Quality®, 2009). This system includes parameters that reflect all areas of ethical concern (i.e. biological functioning, affective state and natural living conditions) and uses a mixture of resource and outcome-based measures, although it does not provide a ready means to link them. Unfortunately, the Welfare Quality® protocol is relatively time consuming to complete (3 to 4 hours), which is one reason for its limited uptake by producers (de Jong *et al*., 2011). Recent research in the Netherlands has sought to reduce the time taken for assessment by reducing the number of parameters that need to be measured (de Jong *et al*., 2011). Measures of severe HB were associated with poor walking ability, but the magnitude of the correlation was rather low (0.44 for conventional indoor-housed meat chickens), therefore deeming these parameters unsubstitutable.

Another potential way to achieve time efficiency is through the use of automated monitoring systems (e.g. of movement patterns) (see Dawkins *et al*., 2013), or by utilising modern digital recording applications on portable devices to collect data and link to other information that is already routinely monitored by farmers.

Monitoring protocols used for compliance purposes are increasingly incorporating outcome-based measures (e.g. European Commission, Broiler Directive, 2007; Kyvsgaard *et al.*, 2013), but do not necessarily include specific mechanisms to engage producers (apart from the threat of sanctions for poor performance). Legislated monitoring requires thresholds for sanctions and external scrutiny of the assessment process to gain public credibility; features not essential for purely benchmarking and continuous improvement programmes (Colditz *et al*., 2014). The success of such programmes is variable. In Denmark, a sanction-based scheme for foot health (monitored in slaughter plants) was associated with a substantial improvement in litter quality and reduction in foot pad scores over the first years. Subsequently, the scores have stabilised at the threshold level for acceptable performance (Kyvsgaard *et al*., 2013), although there are large variations between flocks. The EC Directive on Broiler Welfare (2007), which also targets FPD prevalence (also assessed in slaughter plants), has not resulted in changes in prevalence in Ireland (O'Reilly and McKevitt, 2014) and the outcome for the UK is still not clear (European Commission, 2013). Interestingly, and in line with the findings presented earlier (see section 2. Leg and foot conditions), there are no agreed standards for scoring FPD, and Denmark and the UK differ in the thresholds used for sanctions, indicating the arbitrariness of the chosen thresholds (Kyvsgaard *et al*., 2013; European Commission, 2013).

Standardisation of measures and sampling procedures (e.g. in different parts of a shed) have also been raised as issues in monitoring programmes (e.g. De Jong *et al.*, 2012b; Marchewcka *et al*., 2013). The recorded prevalence of poor gait scores varies greatly with scoring definitions and house sampling protocols (see section 1. Locomotion). Marchewcka *et al*. (2013) estimated that a reliable estimate of welfare in a shed can be obtained when 20% of the area is sampled, which can be achieved by walking a single transect the length of the shed, depending on flock size and condition, and shed dimensions. Marchewcka *et al*. (2013) estimated that a single transect could be scored in 30 to 45 minutes. Parameters observed and recorded (on a tablet) were walking ability (immobile or limping), plumage cleanliness, ill-health, and the number of dead birds (see Marchewcka *et al*., 2013, for full definitions). The absence of measures such as FPD or HB in the current version of the transect methodology are potentially important weaknesses. However, other measures, such as water consumption and litter moisture levels, that can be taken remotely and in real-time, are correlated with poor skin health (e.g. Manning *et al*., 2007a). Thus, digital recording of information obtained during routine transect walks offers the advantage that it could be linked easily in real-time with other routinely recorded measures (such as of feed and water intake and growth, and numbers of culls) (Manning *et al*., 2007b) to provide a comprehensive, efficient and cost-effective way to monitor bird welfare. Real-time monitoring offers the farmer the ability to manage welfare risks before concerns arise.

As noted in other sections of this document, and by EFSA (2012), the validity, repeatability and reliability of many outcome-based measures have not yet been sufficiently well established, and their sensitivity and specificity are low and not necessarily applicable within the Australian climate. There are also gaps in measures for affective states (EFSA, 2012). These issues remain significant challenges for the development of comprehensive, credible welfare monitoring systems. Nevertheless, it is suggested that improvements in chicken welfare could be achieved by introducing industry-wide performance monitoring and benchmarking systems (Colditz *et al*., 2014; Main *et al*., 2014). For market assurance and legislative purposes, scientifically calibrated thresholds and external scrutiny of the monitoring process are required.

Implications

During the systematic literature search, an emphasis was placed on four factors:

- Studies conducted in commercial conditions were given more weight than those conducted in experimental (usually smaller scale) conditions, as these are usually more relevant to field conditions.
- Studies conducted in Australian settings were favoured over studies conducted overseas.
- Recent studies were given more weight than older studies to account for the progress in genetic and other environmental and management factors.
- The quality of the work was assessed objectively, and limitations that could be considered to potentially impact of the relevance or accuracy of the outcomes highlighted in the report.

The literature summarised in this report covers several welfare topics, risk factors and husbandry practices that potentially impact meat chicken welfare and provides a critical review of the available information. The review shows that there is significant uncertainty regarding the types of management practices and housing conditions that impact adversely on chicken welfare. Similarly, most measures of welfare and thresholds for acceptable welfare are not well validated. Thus, modifications to the Model Code of Practice will need to be considered carefully.

In the process of the literature review, it became clear that there is a paucity of published information on Australian housing and management practices and evaluation of chicken welfare under local conditions. The extent of various welfare issues varies between countries. For example, FPD is very high in many European countries, often due to wet litter in winter when it is very difficult to keep humidity low and temperature and ventilation high. However, New Zealand does not seem to experience the same issue (Bagshaw *et al*., 2006), and this may or may not be similar in Australia. Collecting scientific information under local conditions would help assess the extent and relevance of each of the issues covered in this report to Australian meat chickens. It would also help to identify areas where improvements can be made. Modifications to housing and management practices are taking place on many Australian meat chicken farms through the adoption of the RSCPA Australia standards. Objective measurements of bird welfare both before and after the modifications would help quantify the impact of any changes in practices, management or housing conditions.

Stockmanship is widely acknowledged as one of the most important determinants of an animal's welfare (Hemsworth and Coleman, 2011), and on a general level is linked to all aspects of welfare covered in this literature review. Despite its importance, stockmanship has received little attention in scientific studies on chicken welfare, and little published information could be found on the topic. Nevertheless, it is an area worth investigating, as significant improvements in animal welfare and productivity have been shown to be possible with other species, for example by the implementation of ProHand®, a training program based on stockperson attitudes and behaviour (Hemsworth and Coleman, 2011).

Chicken welfare is, and will increasingly be, a major societal concern in Australia with an increasing economic value.

Recommendations

The current document provides a summary of up-to-date verifiable evidence regarding several welfare topics, risk factors and husbandry practices that potentially impact meat chicken welfare. It relies mostly on an international body of published evidence, because there is little published data from birds under Australian conditions for the topics covered in this literature review. The objective from this report is to assist in the review of the Standards and Guidelines for the welfare of meat chickens in Australia. Delivering these findings in the form of a peer-reviewed journal article (e.g. published in the journal ‘Poultry Science’) would ensure external credibility and confidence of the various stakeholders in the objectivity and high scientific quality of this report. It would also provide an objective and unique review document that may differ from the European-centric view of animal welfare that currently dominates the scientific literature. Therefore, this document is intended for submission as a peer-reviewed publication.

In terms of the relevance of this document for the Australian chicken meat industry:

- The scientific evidence provided can be used to support the development Standards and Guidelines in the review of the Model Code of Practice.

- A list of potential welfare indicators could be developed based on up-to-date verifiable evidence regarding key issues for meat chicken welfare. However, further knowledge regarding these issues in Australian environmental conditions is necessary to develop a list of welfare indicators relevant to the Australian chicken meat industry.

- Suggestions are made to improve welfare through monitoring and benchmarking, but this does not necessarily equate to increasing the amount of auditing protocols or compliance schemes. Indeed, the industry already collects detailed data on bird growth, health and environmental parameters. If systematised, this data could be used to standardise chicken welfare within the industry and monitor progress to present to stakeholders.

- A vertically integrated approach is required to achieve long-term sustainable improvements as welfare is often associated to the management and housing conditions during the growing cycle. Nonetheless, experience shows that it is not just management practices in the grower shed that impacts on the welfare of meat chickens, but also at the meat chicken breeder stage, hatchery, the feed provided and the transport and slaughter process.

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