Egg Farming Systems Welfare Science Review

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Foreword

This project was conducted to fulfil industry knowledge gaps and provide a succinct analysis of welfare science relating to current egg production systems. Specifically, this project was undertaken to understand: the balance of scientific literature on conventional cages; the advantages, disadvantages and issues of different egg production systems; and whether the use of conventional cages is associated with poor animal welfare outcomes.

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

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Executive Summary

This summary of the scientific data concerning layer hen welfare in the important production systems in Australia briefly addresses the issues of our understanding of science and the ways that we can assess welfare and how the particular framework and pre-suppositions of the scientist or reviewer will influence the interpretation of the data that is collected in surveys and scientific experiments.

There are basically two accepted measurable frameworks for assessing animal welfare, namely biological functioning and affective states. The former addresses those traditionally measured parameters of disease rates, mortality (death) rates, production parameters and as more emphasis on animal welfare has come to bear, measurements of stress indicators. On the other hand, the affective states framework takes into consideration the behaviours that the birds are motivated to perform. Quite opposite conclusions can be drawn on procedures or types of housing if only one framework is used for assessment.

The main housing systems examined are conventional cages, barn (no free-range access) and free- range. Aviary systems where birds have access to multiple levels within the shed can be either barn or free-range. There are recognised many “benefits” that accrue to birds which are housed in conventional cages, including lower mortality rates, lower rates of bumble-foot, old (and therefore chronically painful) bone breakages, internal parasites, protozoal disease, bacterial diseases, generally better measurable levels of stress indicators, avoidance of range related issues such as grass-impaction, exposure to diseases carried by wild birds and predation from vermin such as foxes.

There are clear benefits of conventional cages in reducing welfare related behaviour such as smothers and cannibalism and protection from predators. The potential negative issues of conventional cages include an increased incidence of Haemorrhagic Fatty Liver disease (which can be managed by husbandry and feeding the correct diet) and osteoporosis (which is more recognised in hens housed in conventional cages).

The historical major problem for hens with osteoporosis is the occurrence of new bone fractures when the birds are depopulated for slaughter at the end of flock life. This problem can be managed and has been by improvements in the way birds are handled at the time of depopulation and by improved nutritional management. Layer hens in conventional cages are prevented from performing behaviours compared to layers when housed in alternate systems and the impact of those restrictions are discussed. There are advantages of conventional cages for farm workers and the environment.

There are considered disadvantages and advantages of the three main housing systems used for laying hens in Australia. These differences are predominantly in the areas of behaviour, health, productivity, environmental impact and economics which will be discussed specifically in this report. As such, there is no relationship between the use of conventional cages and reduced welfare practices, and there is no more relationship between the use of conventional cages and poor welfare outcomes than there is with either free-range or barn housing systems.

There are animal welfare issues to be understood for all housing systems and a rational balance of welfare assessment frameworks should utilised to make assessments of the different housing systems. When that is done it is difficult to insist that any existing cage system leads to better welfare outcomes overall compared to the other alternate systems.

Overall Conclusions

It is clear from this review that no one housing system provides superior welfare when the two measurable welfare assessment frameworks (biological functioning and affective states) are considered. Future assessments of the relative levels of welfare provided by the predominant productions systems within the Australian Egg industry should consider both the evidence of the welfare benefits of any system and the welfare deficits of the replacement systems.

1 Introduction

1.1 Purpose

The purpose of this Report is to produce a plain language summary of the scientific literature on egg production systems used in Australia, noting the advantages and disadvantages, (particularly with respect to animal welfare) of each system. This Report includes information on three production types – conventional cages, barn and free-range. "Furnished" cages will not be addressed as they are not an important production system in the Australian context as they are not used to a significant extent. Some farms use "colony cages" (larger cages housing 40 or more birds) for rearing or for breeding but will also not be addressed separately in this Report. Aviary systems consisting of multiple levels with free access for hens to move up and down the levels within the shed can operate as either barn or free-range.

1.2 Background to understanding science

Scientific research is conducted in the basis of a pre-existing framework of thoughts and values. One of the fundamental assumptions is that what is seen has a cause. From that framework we can examine what we observe by experimental methods. This allows us to support (or disagree with) the theories about those causes. However, there are other assumptions that can impact the way an experiment is designed and the way the results are interpreted. This applies to both experimental observations and what is recorded in real life, for example in production, disease and mortality records of commercial poultry.

1.3 Background to understanding welfare frameworks and perceptions

For most of last century the thinking about animal welfare was primarily concerned with cruelty and its prevention. That is, seeking to prevent actions that would cause unreasonable pain and suffering. Over several decades this has moved to consideration of what can be termed "positive welfare outcomes", whilst of course still including the avoidance of unreasonable pain and suffering.

In many countries', legislation was initially focused on preventing cruelty and gradually this was supported by the introduction of codes of practice that were still designed to ensure all the basic biological needs of animals (food, water, shelter) were met and unreasonable pain avoided. In many countries such guidelines have become supported by legislated standards that now include a consideration of positive welfare considerations as well. Community perceptions have changed over time, particularly with the urbanisation of society with many community members having no contact with farmed animals and farming practices.

The first well-known step in the changing understanding of welfare was the introduction of the "Five Freedoms" principles in 1979. Four of those freedoms reflected the need to provide animals with their basic needs – freedom from thirst and hunger, freedom from discomfort, freedom from pain, injury and disease and freedom from fear and distress. The fifth and newer concept was the freedom to express normal behaviour. This marked the introduction to the concept of animal welfare of a "values-based" judgement. It can therefore be seen that "welfare science" is based on both science and values. The current frameworks used for assessing welfare are discussed below.

1.4 Different assessment criteria

There are currently three frameworks used to assess animal welfare. They are quite different and can be evaluated by the normal scientific method to various degrees. The preference for one or the other explains why we can have quite different views on the same animal welfare data. However, they are not mutually exclusive, and they do overlap.

The first is the more traditional "biological functioning" framework which considers basic health and normal body function, stress responses and some behavioural responses as the main indicators of welfare. This framework is the most appropriate for assessing risks to animal welfare along the traditional understanding of avoiding negative welfare or cruelty.

The second framework is the "affective state", which is based on a definition of welfare as being derived from its capacity for and experience of positive and negative states, experiences and emotions. This assessment looks at the balance between positive and negative experiences but presupposes that a positive state is only possible when the animal is able to carry out innate or "normal" behaviours. This framework includes an original value judgement of what is normal and whilst harder to measure than the biological functioning framework has some aspects that can be measured. These include experiments that can rate the effort a hen will undertake to be able to perform a certain behaviour and mapping the amount of time hens will devote to certain behaviours when free to perform different behaviours.

The third framework which some suggest should be used for assessing welfare is "natural living" and extends the emphasis of affective state on normal behaviours to include the animals living in "natural environments in natural ways". This framework is subjective, difficult to apply meaningfully to domesticated animals and is not considered helpful for the assessment of animal welfare.

Biological functioning and affective state can be used together to assess welfare. Where emphasis is given to only one framework we can arrive at totally opposite conclusions. For example, with respect to hen welfare if we only consider biological functioning, we would conclude that hens should all be kept in cages because the disease and mortality rates in cages are lower than in free-range or barn systems. On the other hand, if we only consider affective states, we would conclude that due to the inability to perform "normal" behaviours in cages that we should only use those systems that provide more space and litter. Both extremes would ignore significant issues with respect to hen welfare.

2 Scientific literature on conventional cages

2.1 Health Benefits

A broad definition of health is used here to include most of the indicators that would be considered in the "biological functioning" definition of welfare and includes mortality from various causes (for example from predation), diseases, injury, especially those which lead to chronic pain, diet related diseases which either occur in cage systems or are avoided in cage systems and negative behaviours that impact health which are also avoided by cage systems.

The many advantages of conventional cage systems for bird health arise from the separation of birds from manure and litter, improved air quality in cage systems (or fully slatted barns), in prevention of bird pile-ups, protection from predators and better protection from the extremes of environment found in free-range systems.

Mortality (death) rate

Has been shown to be significantly lower in conventional cage systems than in free range systems and to be lower or in a few studies, similar to the mortality rates in barn (single-level) facilities. This includes lower mortality from diseases in general (as detailed below), from attacks by predators, from smothering and from free-range related disorders such as grass impaction.

Foot health

In terms of foot health (bumble foot and footpad lesions scores) have been shown to be better in hens in conventional cages compared with the foot health of birds in other housing systems. The impact of conventional cage housing varies with some studies showing an improvement in claw length in caged birds.

Protection from (old) fractures

At processing, evidence of "old" fractures, particularly of the keel bone are found at a much higher incidence in non-caged birds. These fractures are likely to cause chronic pain, as they occur throughout the life of the flock and are in part postulated to be due to collisions with other birds and infrastructure in the barns and range. There is some evidence of these sorts of injuries in cage birds but at a much lower rate. Levels of keel bone fractures in alternative systems of up to 97% have been observed compared to 17.7 – 24.8% in hens in conventional cages.

Parasites

Parasites are divided into those which are "internal" and "external". In general, the occurrence of external parasites is not as greatly influenced by housing system, however the higher level of exposure to wild birds and other animals does increase the exposure of free-range birds to external parasites such as lice which are not always host specific. The actual materials used in construction may to some extent allow greater refuge for red-mites which live for much of their time off the chicken and in the shed environment. There are limited therapeutic options for use in controlling external parasites on egg-laying hens in Australia.

Internal parasites generally have a life-cycle that includes passing via the faeces to the ground or litter and then either via an intermediate host (for example an insect) or directly develop in the litter to the infective stage and are then eaten by the chicken and develop into adults in the chicken.

Chickens develop varying levels of immunity to some internal parasites and so become relatively unaffected by the presence of these parasites as they reach maturity. Other internal parasites can cause pathology in the intestines and clinical disease and untruthfulness with the loss of condition and productivity in hens. Some worms are also carriers of other diseases, notably the caecal worm which can carry the organism responsible for Black Head disease.

Due to the removal of direct exposure to litter and the ground, hens in cage systems generally have much lower rates of infection with internal parasites, and thus the need for treatment intervention with anthelmintics. In chickens these are broadly divided into round worms and tapeworms.

In Australia there is currently no registered product to treat infections of chickens with tapeworms, so that hens raised in non-cage systems are at a distinct disadvantage with respect to protection from tapeworms. There are currently two registered products which can treat roundworms, both of which can impact on water intake in hens and therefore welfare and production. In addition, these are currently being considered for review by the regulator of veterinary chemicals as to their continued use due to technical concerns.

Cage birds in general require no therapeutic or preventative products for the control and treatment of parasites unlike birds in alternative systems where the need for therapeutics is extensive with limited registered products of off label use. Vaccination is not an option for controlling external and internal parasites with no products available or likely to be in the medium term.

Protozoal diseases

Whilst they are strictly classified as parasites, organisms of a similar class to the cause of Malaria (Protozoa) including histomonads and coccidia (*Eimeria spp*.) cause disease in birds exposed to faeces. The diseases are known as "Blackhead" and Coccidiosis, with the latter being very prevalent in floor exposed poultry and requiring either vaccination or the inclusion of preventative products in the feed at an early age (in rear) until immunity develops.

Disease outbreaks require therapeutic treatment in the drinking water. Birds housed in conventional cages have a much lower incidence (essentially nil) of these diseases than layers housed in non-cage systems, once again due to their lower exposure to faeces, litter and soil. Overall with cage birds a significant reduction for the need of preventative or therapeutic drugs or control by vaccination.

Bacterial diseases

In Australia an increase in bacterial disease is seen in non-cage systems including but not limited to, Spotty Liver Disease, Fowl Cholera and Erysipelas, all far more likely to occur in birds with access to the environment where the hygiene cannot be controlled (deep litter and range areas) due to the limited ability to control the ingress of contaminating hosts / vectors such as wild birds, insects and vermin, and this is then exacerbated by the faecal oral cycle. Some bacterial diseases such as those associated with Mycoplasma species have been more effectively controlled in Australia by the introduction of vaccines, but still remain under challenge where biosecurity is more difficult to control in alternative systems.

With the increase of layers maintained under alternate systems there has been a significant increase in bacterial disease causing significant productivity losses compared to caged layers, with the consequence of the need to farm a higher number of hens to achieve equivalent egg numbers and the substantial increase in the need for therapeutic antibiotic treatment where other options such as vaccines or in feed additives are not available or suitably efficacious .

These diseases are rarely seen in caged birds.

Many species of commercial poultry and animals are susceptible to infection by *Pasteurella multocida*, the cause of Fowl Cholera (FC). Layers in barn and free-range conditions are more likely to be infected, with FC essentially unrecognised in caged layers. This disease can cause sudden deaths or more chronic forms of disease and can affect multiple organ systems. Treatment initially requires antibiotic treatment and then a vaccine produced from the organism on the farm can be used to protect new flocks coming to the farm.

The generic vaccination program using the registered live vaccine followed by a killed vaccine has been significantly compromised as the supply of a registered killed vaccine has been discontinued and no commercial registered vaccine is currently available in Australia. The industry is currently relying on autogenous vaccines and minor use vaccines. An autogenous bacterial vaccine has to be custom manufactured for the particular farm from the bacteria isolated from those hens. As the organism has many strains and it may be necessary to continue to manufacture and use new strains on the one farm. As the organism does develop resistance to the one affordable antibiotic registered for use in laying hens in Australia, there are also issues with ongoing effective treatment of some outbreaks and thus the welfare outcome of the inability to control clinical disease and mortalities.

Disease in commercial laying hens in Australia caused by Salmonella is primarily of concern due to its impact on food safety but the organisms can cause clinical disease occasionally. There is evidence of infection in hens in all housing types.
Erysipelas is caused by an organism that survives well in the environment and also infects other animals, particularly pigs, sheep, turkeys and wild birds and is often also causally associated with high levels of rodent activity. The organism can also cause disease in humans (zoonoses). Treatment is with antibiotics and control is aided by the "off- label" use of a vaccine currently available for pigs and sheep.

Spotty Liver Disease also primarily affects free-range and barn hens although the disease has been reported in very uncommonly cages under atypical husbandry and hygiene conditions. The disease affects egg production and mortality in a proportion of affected birds. It can be treated by antibiotics but if the problem persists in a flock the bacteria become resistant to the limited antibiotics available in Australia to treat layers in egg production. The disease is currently considered one of the most important bacterial diseases of laying hens in Australia with considerable industry sponsored research underway. This disease is almost entirely absent in hens housed in conventional cages.

Prevention or control by the use of feed additives is limited and no effective vaccine is yet available but is currently part of an extensive R & D program funded by the egg industry. Infectious coryza is an important bacterial disease of laying hens which persists on multi-age farms due to the issue of carrier birds. The disease is spread by horizontal contacts with other layers or through contact with other avian species, particularly pigeons. Birds housed under alternative systems are at greater risk.

In different parts of the world, and recently in Australia, another bacterium - ORT (*Ornithobacterium rhinotracheale*) has been associated with respiratory disease in poultry, including air-sacculitis and pneumonia. ORT infections affect egg laying productivity and egg quality around the world. ORT has been isolated not only from laying hens, but also from wild birds. In France, ORT has been isolated with a frequency ten-times higher in birds housed in free-range farms compared with indoor housing systems, probably due to a higher contact rate with wild birds.

Peritonitis (which includes air sacculitis in avian species), often involves *E. coli* as a secondary pathogen. Peritonitis can be due to infection entering via damage to the cloaca and reproductive tract where vent pecking is an issue, and a higher incidence of this is seen in layers housed in alterative systems. Peritonitis (with air sacculitis) can also be caused by ventilation inadequacy which can occur in any husbandry system where there are deficiencies in facilitation or husbandry. The disease can be more prominent when other primary pathogens are present and there is a higher risk of that in barn and free-range systems.
As a generalisation it can be stated that hens in conventional cages will experience less disease due to bacteria spread by faecal contamination than hens in non-cage systems.

Potential for transferable viral diseases
Many common viral diseases can be wind born and transferred by vehicles, boots and clothing and other items that move between sheds and farms without adequate quarantine periods or disinfection procedures and are no more common in one farming system than another. There are though noted exceptions to this like Infectious Laryngotracheitis (ILT) which in Australia has a higher incidence in open sided layer sheds. Overall, free-range production systems do expose birds to a greater risk of infection carried by wild birds, particularly in the case of Avian Influenza (AI) carried by water fowl and particularly ducks. The highly pathogenic form of this disease can cause extensive disease and mortality and being an Emergency Animal Disease (EAD) it occurrence in Austria involves mandatory slaughter out and eradication, international notification and thus affects trade with some countries. The primary source of AI in poultry farms is wild and free-living birds, predominantly water fowl. When water fowl and domestic fowl share the same environment, there is a significantly increased chances for the virus to infect laying hens. In France, it was found that free-range mule duck flocks carried 8 different avian influenza

subtypes. In Thailand the virus was reported to be found mainly in free-ranging domestic ducks. Ongoing monitoring of the endemic populations of wild water fowl in Australia indicate that they are positive for AI of multiple different subtypes.

Stress, pain and fear

There are various scientific measures of stress in animals and in poultry we use several including the ratio of two types of white blood cells, the cortisone levels and the "flight or fight" hormone levels. When compared to hens kept in barn or free-range systems, the stress indicators in conventional cage birds are generally similar or lower. The white cell ratio has been shown to be better in hens in cages compared to hens in free-range systems.

Dietary mishaps

Whilst generally similar diets are fed to hens in different housing systems the potential for mortality and ill-thrift due to grass impaction does not occur in conventional cage or other indoor housing systems but can occur in free-range hens. There is also potential access to toxic or taint creating plants in free-range systems whereas birds housed in conventional cages and barns are not exposed to such plants.

2.2 Behavioural Benefits

Feather pecking is a normal social behaviour in hens and can be classed as either gentle or severe. Gentle feather pecking includes light, repeated pecks usually on the feathers of the tail, wings, back and neck of the hen and the recipient hen does not move away. Severe feather pecking includes hard, fast singular pecks on the tail, back, vent and neck of hens and recipient hens tend to move away. Severe feather pecking can lead to injuries and cannibalism.

In one investigation a significant increase in gentle feather pecking was detected on hens within the free-range system compared with conventional, measured as pecks/hen/min (0.38 versus 0.01).
Another survey demonstrated that vent pecking was lower in hens in conventional cages at 6.2% compared with 10% in hens in barn systems and 22.5% in free-range hens. Other experiments have confirmed statistically lower levels of mortality due to cannibalism in conventionally caged hens compared to hens in other systems.

Feather pecking and cannibalism in laying hens has been noted as a serious welfare problem and a major obstacle to the adoption of non-cage systems. Severe feather pecking is associated with an increased risk of vent pecking and of cannibalism and is common in free-range hens and hens with access to perches at certain levels, but not particularly common in hens housed in conventional cages.

In terms of skin damage, vent and abdomen plumage damage and keel damage (which can all be related to behaviour), the hens housed in conventional cages have been shown by researchers to have less problems than hens in barns or free-range systems. In Belgium, a survey of farmers who had switched from conventional cages to other systems found that in their perception, feather pecking, cannibalism, smothering and mortality were all lower in conventional cages.

One major advantage for hens housed in conventional cages is the lack of smothering. Since most smothers are discovered after the event it is difficult to determine the cause but "panic", "recurrent" (also described as passive) and nest box smothers have been described. There are no substantial studies comparing the incidence of smothering in conventional cage, barns and free-range systems. However Australian egg producers who farm with all three systems report that the problem is confined to non-cage systems. Noting that smothers involves 10's to 100's of birds which cannot occur in cages which contain normally 5 or less.

Protection from predation is also an advantage of hens housed in-doors in cages compared to free- range hens. Foxes are a very problematic situation for free range egg producers with mortalities and loss of production being very significant. Ongoing mortalities due to egg peritonitis arise because of the fright and flight activity and other stress associated diseases such as Spotty Liver Disease are heightened.

2.3 Health Deficits

There are two health deficits for birds kept in cages compared to those in other systems, osteoporosis which is associated with a higher proportion of bone fractures at the end of life pick up of the birds and a disease called Fatty Liver and Haemorrhage.
With modern genetics, better husbandry and an improved understanding of the layers nutritional requirements these two conditions have been significantly reduced in cage production. Improved understanding of the handing and welfare at depopulation also improved the outcomes.

Foot Health

Toe pad hyperkeratosis is seen more commonly in caged birds. This condition is generally not considered to be particularly detrimental to bird welfare compared to other conditions such as bumble foot.

2.4 Behavioural Deficits

Behavioural requirements have been assessed in hens used to a particular environment (e.g. access to perches or nests) in several ways. These includes tests of the degree to which a hen will work to gain access to the equipment required for the behaviour (in these examples a nest or a perch). The motivation to access the equipment can be tested by using an obstacle between the hen and the equipment such as weighted gates for the hen to push through. Motivation is judged to be higher depending on the effort the hen will undertake to gain access to the equipment that allows the behaviour.

Another method of evaluating the importance of a behaviour is to measure the amount of time that hens with free access to the required equipment spend on that behaviour, in a sense a daily diary of hen activity. Motivation to lay in a nest is very high in birds used to utilising a nest and the subsequent removal of the nest will lead to an increase in measures of stress. Perching is another behaviour for which hens which have previously been provided with perches will work hard to reach. It appears that the desire for perching on higher perches at nighttime is greater than that to perch during the day.

Evidence that birds which have not had access to perches previously are stressed or "miss" the opportunity to perch is equivocal. No different levels in stress hormones have been observed between birds not provided with perches and those with perches. There have also been mixed findings on measures of stress in birds with access or without access to nest-boxes, even in birds used to having access to nest-boxes.

Other behaviours which conventional cages do not provide the opportunity for include dust-bathing and foraging although with mash feed there is some extent of foraging as hens pick out the particular nutrients needed for that time of the day. It is generally agreed that this is a lower priority behaviour for hens than other behaviours such as feeding, drinking, use of a nest box and perching.

Using the biological framework for assessing welfare the evidence that the lack of expression of certain behaviours in cages is a welfare issue (except for the lack of exercise and potentially related osteoporosis). However, when the affective state framework for welfare assessment is used the lack of behaviours that can be expressed by hens in conventional cages is a consideration in regard to the Five Freedoms. Other behaviours are discussed under the heading space allowance below.

2.5 Space Allowance

Research regarding the welfare of conventional cages has explored how welfare changes with respect to space allowance and how much space allowance is needed to optimise welfare in conventional cages. Research has been focused on the effects of space allowance on biological changes to hens, behaviour and production. In general, as space allowance decreases to 300 cm2, welfare also decreases based on higher mortality, increased stress, lower egg production and poorer feed conversion. In Australia conventionally housed hens have a minimum of 550 cm2. It is worth noting that there is considerable variation in the scientific literature due to the differences in group size and cage dimensions experiments used. It is also difficult to extrapolate the relevance of this data to Australia as the space allowance does not always comply with our current standards and guidelines.

Biological and physiological differences between hens housed with different space allowances (from 542 cm2/bird to 1,648 cm2/bird) have been investigated and have shown no significant differences. Measurements of stress hormone (glucocorticoid), white blood cell parameters that change in response to stress, body weight, egg production, egg weight, changes and egg shell quality were measured from hens housed from 542 cm2/bird to 1,648 cm2/bird. Space allowance was found to have no effect on these biological and physiological measurements of stress in hens. Similarly, other research has found no differences in white blood cell parameters between hens housed with different space allowances. However, other research has reported that reducing space allowance from 1394 to 697 cm2/bird did increase stress hormone levels in hens.
Chickens perform certain behaviours such as preening, head scratching, wing and leg stretching, dust bathing and body shaking, and these are known as "comfort behaviours".

The relevance of the performance of these behaviours to animal welfare is difficult to assess. Even more so space allowance per bird does not account for the capacity for hens to share space and the tendency for hens to cluster in groups (thereby allowing more space for individual birds to perform certain behaviours) as well as the capacity for hens to perform behaviours at the same time (in which case they would require more space per bird). Some research has found that as space allowance increases from 570cm2 to 1045cm2 per bird there is an increase in the performance of head scratching, body shaking and feather raising.

Research has also shown that birds require anywhere from 540cm2 to 1980cm2 to perform activities such as turning around, wing flapping and stretching and preening Recent research has also noted that hens with a larger space allowance had better feather coverage and spent less time sitting down.

There is difficulty in determining an ideal space allowance for hens in conventional cages as there is variation in the scientific literature and multiple factors to consider including biological, behavioural and production. The research suggests that while behaviour of birds does change depending on space allowance this does not necessarily correlate to biological or physiological indication of stress. Emphasis also needs to be placed on total cage size and group size used in the research as there is an interplay of these factors on hen welfare. While there are differences in opinion correlating wellbeing with welfare, physiological fitness and liveability it is clear that overall productivity and the efficiency of egg productivity is significantly higher in layers housed in cages under the current standards applied in Australia.

2.6 Shed Environment

Air Quality
Air-quality due to ammonia and dust is one of the concerns for the environment, occupational health and safety for staff and the welfare and liveability of hens. Whilst an appropriate level of air- quality can be achieved in all production systems this is greatly dependent on facilitation and expertise of farm staff.
Generally, non-cage systems tend to have greater challenges in air quality due to ammonia and dust when compared to cage systems however the ammonia emissions from cage systems are also dependent on husbandry and ventilation and the frequency of manure removal and its moisture content. In systems that use litter, dust levels are generally higher.
Poor air-quality has impacts on hen health as it can cause damage to the upper respiratory tract making hens more susceptible to respiratory disease and has negative effects on production.

Lighting and impact on behaviour
Commercial poultry have been domesticated in controlled light environments for many generations and selectively

bred to prosper under these conditions. Controlled environment conventional cage and barn systems are designed to control light intensity and duration to correspond with the light requirements of these modern day commercial genetic lines.

The standard measurement of light intensity used in the poultry industry is luminal flux which is abbreviated as lux. In these systems light intensity is usually set between 5-30 lux throughout rearing and lay. During lay lighting is usually set below 25 lux because it is well established that higher light intensities can lead to adverse behaviour such as feather pecking and cannibalism. Growth rate, feed conversion ratio and performance have also been found to improve at lower lux, with most investigations indicating that 5 lux is the optimal intensity for growth and welfare. In a study where commercial laying hens were given a preference to choose the light intensity that they spent time in, they showed a significant preference for dimmer light (5 lux) during the light period and selectively laid in 'darkness' (<1 lux). Time spent in between light and darkness was intermittently distributed throughout the day.

An experiment to determine if light intensities affect behaviour, welfare, performance, and egg quality concluded that birds kept in lower light intensity (10 lux) had improved welfare, performance, and reproduction, while the high light intensity (250 lux) had a detrimental effect on both welfare and performance. Further research demonstrated that light intensities higher than 10 lux do not bring any additional benefits and in fact may have negative effects on egg production as they may favour aggressive behaviour, hyperactivity, and cannibalism among hens.

Other experiments have shown that high light intensity during rearing (30 lux vs. 3 lux) increases the prevalence of severe feather-pecking and that higher light intensities are linked to increased pecking and cannibalism. In open sided sheds, which are primarily in alternate and occasionally barn systems, the ability to control light exposure to birds is limited. Principally, it has been well documented in the poultry industry and in peer reviewed publications that birds exposed to this uncontrolled natural light are more susceptible to behavioural problems such as feather pecking and cannibalistic behaviour.

3 The advantages, disadvantages and other issues associated with different egg production systems

3.1 Environment

In Australia it has been determined that free range farming has higher impacts for greenhouse gas emissions and cumulative energy demand compared to cages. This data has been consistent in studies in the United States of America and United Kingdom that state that energy consumption, food consumption, water consumption and carbon footprint have been shown to be greater in non- cage systems.

Air quality

As noted above non-cage systems tend to have poorer air quality due to ammonia and dust when compared to cage systems however the ammonia emissions from cage systems are also dependent on husbandry and ventilation but additionally with the frequency of manure removal. In systems that use litter, dust levels are higher. Air-quality has impacts on hen health as it can cause damage to the upper respiratory tract making hens more susceptible to respiratory disease and has negative effects on production.

Lighting in alternate systems

In alternate systems light intensity is subject to seasonal photoperiods and birds are subject to lighting above 30 lux throughout the day except when in nest boxes. If birds are in outdoor systems such as caravan systems, they will be continuously exposed to high lux levels of up to 10,752 lux throughout daylight hours. Some free-range systems will rear birds in closed barn systems where light can be controlled whilst others may have birds exposed to natural light from an early age.

Consistent low intensity lighting is a well-known way to reduce feather pecking in commercial poultry production. Giving birds the option of low-level light areas in alternate systems is particularly challenging, and not possible in some systems such as caravan free-range operations.

Multiple adverse biological, disease and environmental events can lead to severe feather pecking and cannibalism. One of the most effective and used ways of addressing situations of deteriorating behaviour is decreasing light intensity. In open sided barn or free-range situation there is limited scope to utilise this option.

3.2 Stress level and behaviour

The level of phycological stress in hens can be assessed by measuring the level of cortisone in blood and faeces, and by measuring the ratio of certain white blood cells. In an investigation funded by some European Union countries there were contradictory results for these measures and there was not a clear conclusion in terms of which production system has the lowest levels of stress. The rest of the scientific literature related with this subject also has contradictory findings.

In terms of aggression, some studies have found that birds kept in barn production systems have poorer plumage compared with caged systems, mainly produced by an increase in aggression and feather pecking. Gentle feather pecking was also found to be in a greater proportion in birds kept in free-range systems compared with conventional cages, measured as peck/hen/min (0.38 versus 0.01). It has been shown that feather pecking is associated with stress in poultry.

There is also a higher prevalence of subordinate poor conditioned birds (low weight), suboptimal egg shell quality and higher levels of corticosterone. These parameters are also associated with higher levels of stress in birds housed in barns compared with cages. However, results in regards with corticosterone levels are controversial. One experiment found lower levels of corticosterone in a barn system and there was no difference between conventional cages and free-range hens.

Another method to measure the level of stress in hens is their ability to develop immunity to infection. In this area too there are conflicting results. Some experiments showed a higher immune response in hens in outdoor systems, while others showed higher levels in conventional cage systems. Chickens challenged with the bacterium *Salmonella pullorum* had lower measurable immunity in birds kept in floor pens compared with the chickens in caged systems.

Vent pecking is another parameter related with stress behaviour in poultry. A comparative study demonstrated that vent pecking was lower in birds confined in cages (6.2%) compared with barn and free-range birds (10% and 22.5%, respectively).
A good indicator that has been developed recently in order to measure stress level in birds is the white blood cell ratio. When hens are under stress conditions, the ratio of two common types of white blood cells varies. A recent report has shown that the ratio was better in birds housed in conventional cages compared with hens in the free-range system.
In terms of skin damage, vent and abdomen plumage damage and keel damage, the conventional cage systems has a lower incidence compared with the other systems.

3.3 Health Status

The prevalence of bone fractures has been shown to be lower in conventional cages compared with barn and free-range systems. While the keel bone fractures incidence has been reported at 17.7% - 24.8% in conventional cages. The incidence has been reported as high as 82% in barn kept birds, up to 59.8% in free-range birds and up to a maximum of 97% in aviary systems. Hens kept in barn and free-range systems tend to have less new fractures associated with depopulation at the end of flock life, which as noted above can be managed by better attention to bird handling at the time.

The lower incidence of chronic fractures in hens in conventional cage systems is reported to relate to less frequently observed collisions with other birds and with the shed infrastructure including perches and different levels seen in barn and free-range systems, particularly those which include an aviary (multi-level) component. Whilst bone strength has been shown to be higher in systems where birds move the most, those systems also create more opportunities for collisions, and collisions with greater impact. The companies responsible for breeding stock have been selecting for improved bone strength in laying hens and our increasing knowledge of nutrition has enabled us to better formulate poultry feed in a way that promotes better bone health.

Mortality rate was also found to be lower in birds housed in conventional cages compared with barn and free-range birds. A study showed that the mortality in barn-kept birds increased consistently through time, reaching 0.6% in a period of 6 weeks between 66 and 72 weeks of age, while the increment in mortality was consistently lower in caged birds. At the same time point (66 to 72 weeks of age) the mortality in the birds placed in conventional cages remained as low as 0.1%. In Australia the typical 65-week mortality rates for hens in conventional cages range around a mean of approximately 3% from 2 to 5%, a mean of 5.55% from 4-7% in barn systems and a mean of around 12% for free-range hens (range of 8-30%).

It has been described that non-caged systems, such as barn (aviaries) and free-range, have an increased incidence of infectious diseases and parasites. In terms of bacterial infections, there has been an increase in the incidence of erysipelas, colibacillosis, Spotty Liver Disease and fowl cholera as more hens are housed in alternative systems. Parasitic infestations, such as red mites and helminths, are more commonly found in free-range and floor-based systems compared with caged systems. The greater incidence of infectious and parasitic diseases in non-caged raised hens results from the constant exposure of the birds to soil, litter, faeces and fomites (such as rodents, beetles, equipment) known to carry infectious agents. Another source of infections in the free-range system is the contact of the layers with wild animals, birds and invertebrates , which can carry infectious disease agents either actively or passively.

3.4 Production Parameters

Production parameters in commercial birds are also correlated with their feeling of wellbeing which can be interpreted to be a component of the hen's welfare status. When birds are kept under stressful conditions, this is reflected in lower levels of productivity. In general terms, the best production results can be found in birds housed in conventional cages, as several studies performed in different parts of the world have reported (UK, US, Serbia and France).

Comparative studies show that higher body weights were found in birds housed in conventional cages compared with free- range and barn-housed chickens. Other studies have shown that the best egg production rates, live weights, feed efficiency, and egg and egg shell weights, were found in caged hens compared with floor-pen hens. There is one contradictory study showing that egg production, feed intake and egg mass was better in free-range production system compared with conventional cages. However, this study was conducted under laboratory conditions, and even though the conditions in the conventional cages were very similar to those found in farm, the free-range conditions were different. In this study the experimental free-range system consisted of pens with only 40 birds allocated, which is much easier to manage than a real free-range farm, and where the stress conditions are much lower due to the low number of birds. The same study also showed that the proportion of dirty eggs was higher in the free-range farm, which pose an important risk to the human population in terms of food safety.

Other health-related issues, such as bumble foot and footpad lesions, were found to be higher in free-range production systems compared with the conventional cages. A report from the French branch of the world's poultry science association (WPSA) showed that the laying rate was higher in birds maintained in conventional cages compared with birds laying in on-floor systems. According to the LayWel program (a European review on egg laying systems), the production was less efficient in non-cage systems compared with conventional cages.

In Australia because of deteriorating egg shell quality and decreasing liveability in late lay, free range birds are normally kept only until about 65 to 72 weeks of age, whereas caged layers are normally maintained up until 85 weeks of age or longer. Thus, the unit productivity performance for cage layers is significantly better compared to free range and overall up to 25% less birds placed are used in a cage layer production cycle compared to free range. With the latter being affected by mortality, rate of lay, first grade egg recovery and duration of economic productivity.

4 Conventional cages and welfare outcomes

As with all housing systems there are interpreted benefits and disadvantages of conventional cages with respect to welfare. The assessment method used will greatly impact the overall conclusions. With respect to biological function assessment the welfare of laying hens kept in laying cages is demonstrably superior to hens kept in other systems as outlined above. However, when the affective state framework is also used to assess welfare, the biological functioning benefits of housing laying hens in conventional cages are considered must be balanced with the limitations on the performance of various behaviours. Even though it is hard to define any negative measurable biological impact of the lack of most of those behaviours, hens are highly motivated to perform some of those behaviours (nesting and perching) when they have been accustomed to them previously and this is a relevant factor.

The two main biological issues with conventional cage use (Fatty Liver and Haemorrhage and osteoporosis) can be addressed by changes in management. That includes nutritional management and husbandry improvements, including end of life bird pick up. There are fewer bone fractures in conventionally caged hens throughout the life of the hen in the cage compared to hens from other systems, particularly those with perches. Therefore, osteoporosis is not a particular welfare issue during the cage-life of the hen. However, at pick up, birds from conventional cages have been shown to have higher rates of “new” fractures. These are now reduced by improved bone strength as a consequence of selection and nutritional optimisation and modified changes in the pick-up procedure, such as breast support.

4.1 Sub optimal welfare practices

There is no evidence that the use of conventional cages is any more accompanied by unsatisfactory animal welfare practices than the use of any other housing system. From the data available, it would appear that there is far more variation in the level of husbandry and attention to detail within a particular classification of farming system than there is between the different systems.

With respect to what some would consider contentious animal welfare practices there is evidence that hens in conventional cages have improved welfare outcomes in regard to cannibalism and generally, do not require beak trimming unlike birds in alternative systems where it has been a recognised compromise by welfare advocates that beak trimming does need to be practiced for a risk mitigation against pecking and cannibalism.

4.2 Conventional cages for the modern egg production industry

The original reasons for moving to conventional cage production systems are still relevant today, although progress in the development of improved vaccination strategies does make control of some of the diseases which affect floor-based housing systems more possible than in the past. However, the recognition of welfare problems of not having birds in cages still remain. Egg producers in Belgium who changed from conventional cage systems to alternative forms of housing noted distinct “welfare” problems (in particular, mortality, smothering, and cannibalism) with their hens in those new systems.

The welfare benefits of the conventional cages system include better overall disease control, better control of ambient conditions (compared with free-range systems), less chronic bone fractures, elimination of predation, reduced levels of cannibalism, reduced deaths from smothering, as well as benefits to farm workers and to the environment.

There are environmental advantages with the use of conventional cages which are also outlined above, particularly with respect to air quality and its impact and hen health. There are also economic considerations, which include economic losses associated with higher disease and death rates in non-cage systems. Some reviews on the benefits and welfare problems of various housing systems generally make conclusions based not on a careful and rational weighting of welfare consideration frameworks but on a particular bias towards one framework.

5 Conclusion

Overall the improvement in bird health, the decrease in mortality caused both by disease and behavioural issues such as cannibalism, smothering and predation justify the continuing use of conventional cages for laying hens from a biological functioning perspective. This can be balanced by consideration by the affective states framework but there remains a strong basis for the welfare benefits of conventional cages. The welfare negatives of alternative systems must also be carefully considered. It is clear from our review that no one housing system is superior when the two measurable welfare assessment frameworks are considered, and that any conclusions that suggest the exclusion of one particular system are reached by ignoring evidence of the welfare benefits of that system and the welfare deficits of the replacement systems. This is to be expected given the varying pre-existing views and evaluation contexts used by different reviewers.

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