NATIONAL FARM ANIMAL CARE COUNCIL
CONSEIL NATIONAL POUR LES SOINS AUX ANIMAUX D'ÉLEVAGE

CODE OF PRACTICE FOR THE CARE AND HANDLING OF PULLETS AND LAYING HENS:

REVIEW OF SCIENTIFIC RESEARCH ON AMENDMENT TOPICS

Pullets & Laying Hens Code of Practice Scientific Panel

February 2025

Tina M. Widowski, B.S., M.S., Ph.D. (Chair)
Professor, Department of Animal Biosciences
Egg Farmers of Canada Research Chair in Poultry Welfare
University of Guelph

Alexandra Harlander, Mag.med.vet, Dr.med.vet, PD, DECAWBM-AWSEL
Professor, Department of Animal Biosciences
University of Guelph

Mike Petrik D.V.M., M.Sc.
Adjunct Faculty Member,
Ontario Veterinary College, University of Guelph
Director of Technical Services
McKinley Hatchery Inc.

Josiah Mullet Koop B.Sc., M.Sc.
Research Writer

Glen Jennings (ex-officio)
Pullets and Laying Hens Code Amendment Committee Chair
Egg Farmers of Canada

SCIENTIFIC COMMITTEE
NATIONAL FARM ANIMAL CARE COUNCIL

PUBLISHED 2025

ACKNOWLEDGEMENTS

This report was a significant undertaking, and we benefited from the help and guidance of a number of people. The Scientific Panel would like to thank the following for their contributions to this report: Dr. Stephanie Torrey, who served as the Peer Review Coordinator; the three anonymous peer reviewers; and Code Amendment Committee Chair Glen Jennings from Egg Farmers of Canada who provided industry expertise and many valuable comments that helped to make the text clear and relevant.

Financial support was provided by Agriculture and Agri-Food Canada through the AgriAssurance Program under the Sustainable Canadian Agricultural Partnership.

EXCERPT FROM THE SCIENTIFIC PANEL TERMS OF REFERENCE

Background

It is widely accepted that animal welfare codes, guidelines, standards, and legislation should take advantage of the best available knowledge. This knowledge is often generated from scientific literature.

In re-establishing the Code of Practice development process, NFACC recognized the need for a more formal means of integrating scientific input into the Code of Practice process. The Scientific Panel's review of research provides valuable information for the Code Amendment Committee that is tasked with amending the Code of Practice for the Care and Handling of Pullets and Laying Hens. The research report will be publicly available, enhancing the transparency and credibility of the Code.

Purpose & Goals

The Scientific Panel will develop a report synthesizing the results of research relating to specific amendment[1] topics, as identified by the Code Technical Panel (CTP). The report will be used by the Code Amendment Committee to amend the Code of Practice for the Care and Handling of Pullets and Laying Hens.

The Scientific Committee's report will not contain recommendations following from any research results. Its purpose is to present an objective, unbiased compilation of the scientific findings.

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[1] From the glossary of the NFACC Code process:
Code amendment: a Code amendment alters, adds to, and/or subtracts from a section or subsection in an existing Code of Practice. Unlike a full update, Code amendments involve a defined and limited number of Code topics that are opened up to potential changes.

PREFACE

This document, compiled by the Scientific Panel (SP), covers research on three specific topics that were identified by a Code Technical Panel (CTP). A CTP is established by the lead industry group (Egg Farmers of Canada for this Code) and consists of sufficient expertise from the original Code Committee and/or Scientific Committee. Representation must include the relevant commodity association(s) or specialized industry group(s) and:

- research or veterinary community
- national animal welfare advocacy association
- other expertise as needed.

As part of the mandated five-year Code review, the egg production sector's CTP recommended that a Code amendment be initiated. Three topics were identified to amend the existing Code (published in 2017). While amendments to any Code must be developed in accordance with NFACC's Code Development Process, it should be noted that the steps related to the review of scientific literature can be omitted or modified as recommended by the CTP. For this Code amendment, the CTP determined that a review of research was necessary for all three amendment topics, as follows:

i. Round Feeder Space for Pullets and Laying Hens
ii. Minimum Space Allowance in Multi-Tier Systems for Pullets
iii. Maximum Number of Tiers in Multi-Tier Systems for Pullets and Laying Hens

As in the Code of Practice for the Care and Handling of Pullets and Laying Hens (NFACC, 2017), the terms "chick," "pullet," and "hen" are defined as follows for purposes of this report:

Chick: A young bird from the time of hatch until fully feathered, which is usually between 14 to 21 days of age.

Pullet: A young female domestic fowl from the point it is fully feathered and that has not yet reached sexual maturity (i.e., begun to lay eggs).

Hen: A female domestic fowl that has reached sexual maturity (i.e., begun to lay eggs).

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CONCLUSIONS

1. **There is a positive relationship between measures of well-being and feeder space. A minimum amount of feed space is required for good welfare.**

2. **Feeder space, feeder distribution, arrangement of perches around feeders, and group size all interact to provide the food consumption environment that the birds experience.**

3. **Biometric analysis via digital images of brown- and white-feathered hens reveals that brown hens are physically larger and thus need more space to access the feeder. The larger bird size impacts both their physical space requirements and their feeding behaviour, including competition and personal space, affecting feeder space required to provide good welfare.**

4. **In addition to physical space needed to perform feeding behaviour, social factors such as synchrony and attraction, and conversely competition and social distancing influence the behavioural space requirements for feeding.**

5. **Scientific evidence shows that synchronization of feeding behaviour results in a maximum of 70% of hens or pullets eating at once, especially in large groups where round feeders are utilized.**

INTRODUCTION

Assessing feeder space allowances and the impacts on the welfare of laying hens and pullets requires consideration of the hen's biological functioning, affective states, and natural living (as per NFACC Scientific Committee Terms of Reference, available at https://www.nfacc.ca/code-development-process#appendixb). The biological functioning of the hen includes evaluating performance indicators such as egg production, body weight, and feed conversion ratio, and outcomes such as health and body condition. Affective states represent hens' subjective experiences and what they may be feeling as a result of feeder space allowances. This includes preventing suffering from negative affective states like hunger, pain, and fear and providing an environment for hens to experience positive states. Natural living will be addressed in terms of the ability of hens to interact with the feeder and with group mates in a way that allows for the expression of species-specific behaviours.

This review is intended to inform the requirement for feeder space allowance for round feeders in non-cage systems for both pullets and laying hens. Due to a lack of research on round feeders, research on linear feeder space, especially in group sizes larger than those kept in conventional cages, will be included and, where possible, will be related to round feeders. Discussion of feeder space allowances in other commercial poultry species can provide insight into feeder provision's effects on chickens' behaviour and well-being. Although broiler chickens, for example, differ from layers in terms of growth rate and appetite and, consequently, their feeding behaviour (Bokkers & Koene, 2003), some studies that address the effects of space allowances of round feeders on broilers will be included here for context.

Searches were conducted using Google Scholar, Web of Science, and OMNI, the University of Guelph Library search tool. Citation mining techniques like the "cited-by" feature in Google Scholar were used to find relevant articles. Keywords and phrases that were used included space, feeding synchronization, competition, aggression, agonistic behaviours, social facilitation, laying hens, pullets, floor, non-cage, aviary, furnished cages, and round and linear feeders. Search operators like "AND" and "OR" were used to search various spelling of keywords both individually and as search strings. Literature searches included peer reviewed publications, theses, and scientific opinion articles. Abstracts of search results were sorted by title and abstract: papers that fit within the scope of this literature search were used.

PHYSICAL SPACE REQUIREMENT FOR FEEDING

A first step in determining animal space requirements is using biometric data, or the physical space occupied by an animal's body when performing a particular behaviour (Petherick, 2007). In the case of feeding behaviour, linear body width is considered to be the relevant body measurement and has been determined for different strains of laying hens (Briese & Spindler, 2013; Riddle et al., 2018) and layer pullets (Giersberg et al., 2017). Briese and Spindler (2013) used 2-dimensional digital images of the frontal view of Lohmann Brown (LB) and Lohmann Selected Leghorns (LSL) hens to quantify body widths at 19, 36, and 52 weeks of age. Body widths did not differ across ages, but they were significantly different between strains. Body weights and widths averaged 1.93kg and 15.3cm for LB and 1.73kg and 13.4cm for LSL, respectively. Giersberg et al. (2017) used similar measurements of Lohmann Brown, Lohmann Tradition, and Lohmann Selected Leghorns pullets at 8, 12, and 19 weeks of age. The average widths of brown pullets at the three ages were 10.8, 10.7, and 13.9cm, and 10.3, 10.4, and 12.6cm for white pullets. Using still images captured from video recordings, Riddle et al. (2018) determined the space occupied by four strains of adult laying hens when performing several key behaviours at 28 weeks of age. From top-down views of the birds, they estimated the average widths of Dekalb White (DW), Hy-Line W-36 (W), Hy-Line Brown (HB), and Bovans Brown (BB) hens to be 15.5, 14.9, 18.6, and 19.3cm, respectively, when the birds were standing. Although body weights were not significantly different between strains when the hens were video recorded (DW: 1.61, W36:1.58, HB: 2.06, and BB: 1.98kg), the brown strains of hens occupied significantly more space when standing than the white ones.

FEEDING BEHAVIOUR AND GROUP INTERACTIONS

Social Facilitation, Synchronous Feeding, and Clustering in Space

Feeding behaviour is influenced by a number of social factors that, in turn, affect how feed space, feed availability, and feed distribution impact bird well-being (Petherick, 2007). Early research conducted by Mills & Faure (1989) showed that hens ate more when in visual contact with other hens feeding and tended to feed in the same locations despite multiple food-eating sites. Keeling and Hurnik (1993) conducted a similar study with hens either adjacent to a cage with a conspecific or a cage without. They found the same effect: hens ate more when they could see other hens feeding, even if they were not in the same physical space. Thus, laying hens in small groups synchronize their feeding behaviour in time (Keeling et al., 2017) and cluster together in space (Collins et al., 2011; Keeling et al., 2017).

In the wild, animals synchronize their behaviour in order to increase the probability of finding resources and reduce the risk of predation (Keeling et al., 2017). Because laying hens are motivated to synchronize feeding behaviour, Meunier-Salaun and Faure (1984) and Appleby (2004) suggested that space allowance for feeders had to provide at least enough space for synchronous feeding, which served as a baseline to calculate simple feeder space requirements and was a major consideration in determining feeder space requirements when hens were housed in relatively small group sizes in conventional cages. However, larger group sizes and more complex housing systems provide increased behavioural stimulation, which could result in a lower drive for this synchronization. Keeling et al. (2017) studied the effect of group size on synchrony (in time) and clustering (in space) of feeding, drinking, perching, and preening while on a perch in layer pullets. In group sizes of 15, 30, 60, and 120 pullets, synchronization of all these behaviours decreased exponentially with increasing group sizes. Of all behaviours measured, feeding was the most clustered in space, but the clustering of feeding also significantly reduced with increasing group size, despite the feeder space remaining constant at 4cm/bird. The authors suggest that the ability for all birds to synchronize behaviour may be important for welfare in small groups, but less important in large ones. Interestingly, Thogerson et al. (2009a) found that in conventional cages it was rare to observe all 5 hens feeding at the same time, even when provided with more than adequate feeder space of 12.2cm/hen. It should be noted, however, that competition for a limited resource may also reduce synchronization (Keeling et al., 2017).

Diurnal Feeding Patterns

The feeding behaviour of chickens is not evenly distributed throughout the day, and laying hens tend to eat more at the end of the day (Savory, 1980), which may limit feeder space during peak feeding times. For laying hens in large furnished cages, Blatchford and Mench (2014) found that the maximum number of birds feeding simultaneously was 42 in 60-bird cages (70%). In enriched cages housing a range of group sizes from 28 to 80 birds, Widowski et al. (2017a) observed the average percentage of birds feeding simultaneously was 35%, with a maximum of 63% feeding at the same time. In both of these studies, feeder use was highest during the two to three hours prior to lights out, but there was unoccupied feeder space, indicating that all birds were not motivated to eat at the same time.

Competition and Aggression during Feeding

Although hens may be attracted to one another during feeding, limited feeding space can result in competition and aggression. However, it should be noted that as group size increases, levels of aggression are reduced as hens appear to switch from maintaining a social hierarchy to a system of social tolerance (D'Eath & Keeling, 2003). This requires consideration in furnished cages and cage-free environments where the group sizes can vary significantly. Inter-individual distances can also impact the likelihood and severity of aggression, and it can be challenging to determine an optimal level of space between hens to minimize negative social interactions (Keeling, 1995).

Behavioural measures can help assess how much feeder space to provide chickens (Nielsen et al., 2016). The use of the feeders in terms of time spent at the feeder and the frequency of visits to the feeder may reflect how sharing feeder space affects group members' feeding behaviour, and both measures have been shown to be impacted by feeder space allowance (Oliveira et al., 2019) and feeder design (Meunier-Salaun & Faure, 1984). Behavioural observations can also be used to directly measure displacements at the feeder and aggressive pecks to the head, which are normal agonistic behaviours but likely indicate frustration and fear (Duncan & Wood-Gush, 1971). Indirect assessments of aggression can be made by scoring body or feather condition, for example, injuries to the comb and feather damage at the back of the head (Bilcik & Keeling, 1999; Welfare Quality Network, 2019), although indirect measures can be challenging to determine if aggression is a result of feeder space or competition at other amenities.

RESOURCE DISTRIBUTION AND FEEDING BEHAVIOUR

It has previously been shown that space use by hens is impacted not only by available quantity but also by the design and distribution of other resources (Leone & Estevez, 2008). Keeling (1995) reviewed the spatial behaviour of laying hens and the difficulty in assessing space requirements. In aviary and other free run/floor systems, the space used by hens can be variable and dependent on the system's complexity and design, which, as Keeling (1995) discusses, makes determining the space requirements for resources difficult.

Sirovnik et al. (2021) explored the concept of the Ideal Free Distribution (IFD), a theoretical model used in behavioural ecology that predicts optimal resource use in animal populations. In the case of feeding behaviour, this model assumes that animals eating at a feeder will be proportionate to the distribution of the resource. They tested feeder spaces of 4, 8, 10, 18, and 27cm/bird in pens with 20 hens. At 4, 18, and 27cm/bird, resource use proportions did not fall within predicted values by the model, suggesting that there are other factors at play like aggression and displacement of others at low feeder space provision, and individual preferences and social attraction at higher space provision. Feeding behaviour at feeder spaces of 8 and 10cm, however, did fall within the predicted values leading to a conclusion that 8 and 10cm of feeder space is sufficient for all hens to distribute themselves proportional to available space.

The effect of platforms and perches by the feed trough demonstrates how the complexity and specific design features of certain environments can impact feeding. For example, Sirovnik et al. (2018a) used two brown laying hens of the "Nick Chick" strain in 8 pens of 196 hens, each with 8cm/hen of feeder space. Hens were tested with two treatments of either perches or platforms placed below the feed trough. Results showed that aggression and jostling at the feeder were lower when feeders were set to allow feeding from perches. In another study, Huon et al. (1986) tested groups of three laying hens housed in litter floor pens with partitioned and unpartitioned feeders. There was a positive relationship between time spent feeding and feeder length in these small groups, but when feeders were partitioned into different sections to alter feeder distributions, unpartitioned feeders resulted in longer feeding times and longer feeding bouts, despite both partitioned and unpartitioned feeders providing the same overall feeder space. In furnished cages, Blatchford and Mench (2014) and Widowski et al. (2017a) showed that feeding occurred differently in various quadrants of a furnished cage, resulting from the layout of other resources like nests. Placement of feeders must consider spacing between other amenities to minimize aggression and encourage positive feeding behaviours. These studies demonstrate the difficulty in deciphering the multiple factors that impact feeding behaviours and that this variability is increased with more complex environments.

COMPARISONS OF FEEDER SPACE ALLOWANCES ON BEHAVIOUR AND PERFORMANCE

Very few studies have directly compared feeder space allowance's effects on behaviour and biological function measures in laying hens and pullets. A summary of the main effects from different studies can be found in Table 1.1. Because strain and group size can influence physical space requirement and synchrony of feeding behaviour, respectively, strains and group sizes used in the reviewed studies are indicated.

Laying Hens

Thogerson et al. (2009a,b) studied groups of five Hy-Line W-36 hens in conventional cages provided with either 5.8, 7.1, 8.4, 9.7, 10.9, or 12.2cm of feeder space per hen from 20 to 68 weeks of age (16 cages/treatment). The hens spent less time feeding when feeder space was lower and their feeding was desynchronized, but the authors reported almost no aggression and no mortality. Feeder space did not affect body weight, feather scores or body weight uniformity. Egg production and egg weights were affected, but the differences were small and not linear. Measures of stress response (H:L ratio, heart, spleen, adrenal weights) and bone integrity (bone mineral density and bone mineral content) were not different across treatments. Hens with lower feeder space allowance had poorer feed conversion, which the authors attributed to greater feed wastage. Because aggression was low, body weight and uniformity were similar, and stress measures were not different, the authors concluded that although the lower feeder space resulted in birds desynchronizing feeding, it did not limit feed intake or impair hen welfare.

Oliveira et al. (2019) studied a single group of W-36 white laying hens in a 60-bird furnished cage. They examined linear feeder space of 6.5. 8.5, 9.5, and 12cm/hen, when hens were housed at a constant floor space allowance of 750cm^2/bird. Each hen in the cage was fitted with a Radio Frequency Identification (RFID) tag that allowed for tracking of individual hen behaviour. To test the effect of feeder space allowance, they started with 12cm/hen and reduced the feeder space by partitioning off sections of the feed trough. After the hens' acclimated to the 12cm/hen space allowance, the feeder space reduction treatments were applied by randomization, going from 12 to 6.5, then 8.5, and finally 9.5 cm/hen. Each change in feeder space lasted for 7 days and data were collected during days 3–7 of each treatment period to allow 2 days for acclimation to the new feeder space. The highest maximum percentage of hens observed simultaneously at the feeder was 59% at the feeder space allowance of 12cm/hen. The average hen occupancy at the feeder was also highest at 12cm/hen. Lower feeder space decreased the synchronization of feeding behaviour and each hen's overall time spent at the feeder. The frequency of visits to the feeder was higher at 12cm/hen than 9.5cm/hen and 8.5cm/hen but was not different between 6.5cm/hen and 12cm/hen. It should be noted that they observed high variations between individual hens for both overall time spent and frequency of visits to the feeder. Despite higher frequency of feeder visits and more time spent feeding at 12cm/hen, no numerical difference was found between the daily feed intake at the different treatments. There were also no numerical differences in egg production or water intake for the different weeks at the different treatments.

Widowski et al. (2017a) compared feeding behaviours of Lohmann Selected Leghorn-Lite hens at two linear feeder space allowances, 8.9cm/hen and 12.8cm/hen, in two sizes of furnished cages. Four different group sizes of hens were used to apply four different stocking densities by group size treatments (28 and 40 hens on 20,880cm^2 cage floor and 55 and 80 hens on 41,296cm^2 cage floor), which resulted in confounding of group size, floor space allowance (520 and 748cm^2), and feeder space. Synchronous feeding (absolute number of hens feeding simultaneously) was observed to be higher at 8.9cm/hen feeder space compared to 12.8cm/hen, but the percentage of birds in the group feeding at the same time was not different across treatments. Overall, the percentage of hens observed feeding simultaneously reached a maximum of 63% out of all treatments, and indicated that hens did not utilize all of the available space, as the number of birds feeding simultaneously did not increase as space increased. The average maximum percentage of synchronous feeding was not different between the treatments. Overall, aggression was low, and there was no difference in the frequency of aggressive pecks between feeder spaces of 8.9cm/hen and 12.8cm/hen in group sizes of 40 and 28 in the small furnished cages and 80 and 55 in the large furnished cages. However, lower floor and feeder space allowance resulted in more displacements at the feeder. Widowski et al. (2017b) reported measures of health and production from the same groups of hens. There were no treatment differences in egg production, egg traits, mortality, keel bone deformities, femur, tibia or humerus breaking strengths, and foot health and no consistent differences in body weight or uniformity. Feather condition and cleanliness were poorer at the lower floor/feeder space allowances. Feed disappearance was higher in the smaller groups, regardless of space allowance.

Albentosa et al. (2007) also studied the effects of furnished cage stocking density on laying hen behaviour in one flock of ISA and Babcock brown and one flock of Shaver and Hy-Line brown. The cages were stocked between 609 and 870cm^2/hen for flock 1 with group sizes of 7–10 hens and 609, 762, and 1016cm^2/bird for flock 2 with group sizes of 6, 8, and 10 hens, respectively. Although the authors also did not look at feeder space allowance specifically, their results indicated findings similar to those of Widowski et al. (2017a) with respect to synchronous feeding. Despite adequate feeder space to accommodate synchronous feeding, all hens did not feed at the same time. Overall, hens seemed to show higher synchronization as feeder space increased but did not maximize the space provided. Overall, synchronization of feeding seems to be impacted by feeder space allowance in furnished cages, but out of all the spaces provided, only 60–70% of hens typically fed at the same time in both of these studies.

Sirovnik et al. (2018b) evaluated the impact of feed space allowances of 3.8, 6, 8, 9, and 10cm/hen**,** in quasi-commercial aviaries housing Lohmann Selected Leghorn (LSL) in groups of 200 hens/pen (4 pens/treatment) on behaviour, access to the feeder, and production. Both aggression (vigorous pecks to the head) and jostling at the feeder decreased with increasing feeder space, although jostling also interacted with age (highest when birds were younger); aggression was observed at all feeder space allowances but tended to decrease with age. Authors estimated synchrony (simultaneous feeding) averaged 12.2 to 19.2% of hens and maximums of 34.8% to 65.2% for feeder spaces of 3.8 and 10.2cm, respectively. Treatment did not affect body mass, feather coverage, mortality (~3.2%), or egg production, although feed disappearance and feed conversion (kg feed/kg eggs) decreased with increasing feeder space. Authors reported that local densities at the feeder were inversely proportional to feeder space and increased during feeding times.

Reporting only production data, Diarra & Devi (2014) compared feeder spaces of 5.6, 8.4, 11.2, 14, and 16.8cm/hen in floor pens housing groups of 20 Shaver Brown laying hens with wooden trough feeders. Data collected between 18 and 33 weeks indicated that flock uniformity and age at first egg were lower in groups with 5.6 and 8.4cm/bird of feeder space compered to those with 11.2, 14, and 16.8cm/bird. Hen-day egg production increased with feeder space up to 14cm/hen but was not different between hens with 16cm/hen and those at lower feeder space. Feed conversion was affected but was not linear across space allowances.

Layer Pullets

Anderson & Adams (1992) measured the performance of Babcock (white) layers reared in conventional rearing cages when the pullets were reared with 2.7 or 5.4cm/hen feeder space, stocking densities of 193 or 222cm^2, and 1 versus 2 drinker cups per 7 birds. Pullets raised on 2.7cm of feeder space per bird had lower 18-week body weights and ate more and gained more weight during the laying period compared to those with more feeder space. Hens reared at 5.4cm/bird had poorer feed conversion during lay. There was no effect of feeder space on scores for fearfulness.

Anderson & Adams (1994) housed Babcock (white) layer pullets on either barren litter floor pens or in brooding cages and measured production, skeletal development, and fearfulness of birds reared at different feeder space allocations. Tube (round) feeders were used in floor pens, and linear troughs were used in cages, with feeder space allowances of 2.7, 4.0, and 5.4cm/bird in both systems. There was a positive linear effect of increasing feeder space on body weight from 12 to 18 weeks. There were no treatment effects on bone length, strength, ash, or breaking, but pullets from floor pens had larger intestines, which corresponded with higher feed intake. Applying the tonic immobility testing method to assess fearfulness, they found that the pullets had longer durations to right themselves (more fearful) when reared in floor pens compared to cages, but fearfulness was not affected by feeder space.

Broiler Chickens

Li et al. (2021) compared feeding behaviour of broiler chickens with round feeders at different feeder space allowances and with different numbers of feeding spaces. Sixteen groups of 45 broilers were housed in identical pens and assigned one of four treatments: 2.3cm/bird of feeder space with one round feeder, 2.3cm/bird and 4.6cm/bird with 3 partially blocked round feeders, and 6.9cm/bird with 3 fully open round feeders. The blocking was done on all adjacent feeding slots so that the proximity between the birds was the same for both the single and multi-feeder treatments. This allowed them to observe how the feeder space allowance and the spatial distribution around the feeders impacted birds. RFID monitors were used to track and monitor the broilers' behaviour between 5 and 8 weeks of age. Although this study did not report body weight, it should be noted that broiler chickens at 5–8 weeks of age are heavier and have considerably larger breast sizes (widths) than adult laying hens and would therefore require more space between adjacent birds. They found that daily feeding time and the number of feeder visits were higher for broilers with access to more feeders in more locations despite the same feeder space allowance of 2.3cm/bird. The maximum number of birds feeding simultaneously followed the same trend. It was also noted that the chickens did not utilize all the available feeding slots when feeding simultaneously. They saw daily feeding time was lower when only one feeder was provided compared to three.

Purswell et al. (2021) divided broiler chicks into 24 floor pens (60 per pen), each equipped with 3 tube (round) feeders. They tested 3 feeder treatments of 2.3, 4.6, and 6.9cm/bird. Feeders were partially blocked to achieve the desired feeder space. With increasing feeder space, body weight gain and feed conversion (f:g) were better in the starter phase, and body weight was improved during both the starter and grower phase, but this was not observed in later phases. The overall feed conversion was poorer in the 6.9cm/bird feeder space when compared to 2.3cm/bird.

Table 1.1: List of references that make direct comparisons of feeder space allowance and overall significant findings.

Type of Housing	Reference	Feeder Style	Group Size	Life Stage and Housing Environment	Feeder Space	Effects on Synchronization	Behavioural Measures	Biological Measures
LAYING HENS								
Conventional Cages	**Thogerson et al. (2009a,b)**	Linear	5	Hy-Line W36 laying hens in conventional cages from 16.5-68 weeks of age (WOA)	5.8cm, 7.1cm 8.4cm, 9.7cm, 10.9cm, and 12.2cm/hen	Synchronization was lower at lower feeder spaces Rare to see all hens within cage eating at the same time even with 12.2cm/hen	Time spent at feeder decreased with decreasing feeder space Very little aggression observed	No effect on egg production No effect on Body Weight (BW) or BW uniformity No effect on feather scores Bone density and mineral content not affected H:L ratio not affected More feed consumed/eggs laid at lower feeder space
Furnished Cages	**Oliveira et al. (2019)**	Linear	60	W36 Laying hens in a furnished cage at 21 WOA	6.5cm, 8.5cm, 9.5cm, and 12cm/hen	Maximum of 59% of hens feeding at the same time (at 12cm). 6.5cm showed a maximum of 53% Average hen occupancy was highest at 12cm/hen	Time spent at feeder decreased with decreasing feeder space, lowest at 6.5cm	No effect on egg production Feed intake not affected
Furnished Cages	**Widowski et al. (2017a,b)**	Linear	20–80 birds per cage	LSL Lite Laying hens in 30 and 60 bird furnished cages at 18 WOA	8.9cm and 12.8cm/hen	Maximum of 63% of hens fed at same time Synchronous feeding was higher at 8.9cm/hen	No difference in the frequency of aggressive pecks Lower feeder space and space allowance showed more displacements at feeder	No effect on egg production or BW uniformity Keel bone deformities and other bone characteristics not affected
Furnished Cages	**Albentosa et al. (2007)**	Linear	7–10 birds per cage	ISA Brown and Babcock reared on deep litter with no perches then housed in furnished cages from 16 weeks	12cm/hen	Hens did not all feed at the same time, even when adequate space was available	No data	No data

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Type of Housing	Reference	Feeder Style	Group Size	Life Stage and Housing Environment	Feeder Space	Effects on Synchronization	Behavioural Measures	Biological Measures
Aviary	**Sirovnik et al. (2018b)**	Linear	200 birds per pen	LSL laying hens in commercial aviary design at 21 WOA	3.8cm, 6cm, 8cm, 9cm, and 10cm/hen	Synchronous feeding increased with feeder space Maximum hens feeding at the same time ranging from 34.8%–65.2%	Aggression decreased with increasing feeder space, although aggression was still seen at all levels Jostling decreased with increasing feeder space	Increasing feeder space resulted in more feed consumed/eggs laid No effect on BW No effect on feather coverage No effect on egg production
Aviary	**Sirovnik et al. (2018a)**	Linear	196 birds per pen	White and Brown Nick laying hens in an aviary at 21 WOA- tested effect of feeding from platform or perch	8cm/hen	Maximum of 67.4% of hens feeding at the same time Lower synchronization when eating from perches	Aggression was decreased when hens were able to feed from perches	No data
Floor	**Diarra & Devi (2014)**	Linear	– 20 pullets per pen	Shaver brown laying hens in barren floor pens at 18 WOA	5.6cm, 8.4cm, 11.2cm, 14cm, and 16.8cm/bird	No data	No data	Egg production increased with increasing feeder space, peaking at 11.2cm and decreasing after 14cm/bird Poorer uniformity was observed in 5.6cm and 8.4cm/bird Birds at 11.2cm and 14cm/bird consumed the lowest amount of feed/eggs laid

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Type of Housing	Reference	Feeder Style	Group Size	Life Stage and Housing Environment	Feeder Space	Effects on Synchronization	Behavioural Measures	Biological Measures
LAYER PULLETS								
Conventional Cages	**Anderson & Adams (1992)**	Linear	14 chicks per cage during rearing 4 birds per cage during lay	Rearing and laying phase of Babcock laying hens in conventional cages (day old – 18 WOA for rearing, and 18-60 WOA for laying)	2.7cm and 5.4cm/bird	No data	Fearfulness scores did not differ	2.7cm/bird feeder space during rearing resulted in lower 18-week BW and lower feed intake during lay
Cages and Floor	**Anderson & Adams (1994)**	Linear for cages Round for floor pens	14 chicks per cage	Babcock pullets reared in brooding cages (14 birds/cage) or floor pens (119 birds/pen) until 18 WOA	2.7cm, 4.0cm, and 5.4cm/hen	No data	No effect of feeder space on fearfulness based on latency of tonic immobility	Linear increase on 18-week BW with increasing feeder space No effect on bone quality or bone strength
BROILERS								
Floor	**Li et al. (2021)**	Round	45 broilers per pen	Broiler chickens in floor pens	2.3cm, 3.6cm, and 6.9cm/bird	Chickens did not utilize all available feeding space to feed at the same time	Daily feeding time decreased when only 1 feeder available vs. 3 despite same feeder space of 2.3cm/bird	No data
Floor	**Purswell et al. (2021)**	Round	60 broilers per pen	Broiler chickens in floor pens	2.3cm, 4.6cm, and 6.9cm/bird	No data	No data	More feed consumed/weight gain was seen at 6.9cm

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2. PULLET SPACE ALLOWANCE IN MULTI-TIER SYSTEMS

CONCLUSIONS

1. **There are few studies that directly compare the effects of different rearing space allowances on measures of welfare for growing pullets and adult hens in non-cage systems.**

2. **Complex interactions increase with group size, making it difficult to determine how space allowance alone affects welfare in non-cage systems; therefore, determining minimum space requirements in non-cage systems is challenging.**

3. **The physical space occupied by pullets is different for brown and white strains (e.g., area covered during standing and sitting, respectively, averaged 434.5cm^2 and 456cm^2 for Brown-feathered and 361cm^2 and 380cm^2 for White-feathered strains at 18 weeks of age).**

4. **Although activity levels decrease in a natural progression as pullets grow, reduced space allowance can restrict locomotion. The ability to perform different forms of locomotion (i.e., ground and aerial behaviour) is critical for the development of growing pullets destined for non-cage systems.**

5. **High stocking density during rearing is a risk factor for feather pecking in both the rearing and laying phases of production and can lead to poor plumage condition.**

TERMS AND DEFINITIONS

This review will discuss floor space requirements for pullets which are typically expressed as stocking densities and/or space allowances. These terms are often confused and sometimes misused or used interchangeably. It is critical to identify the definitions of these terms to ensure results are accurately interpreted.

Stocking Density

Stocking density refers to the number of animals per unit of space. When expressing stocking densities (i.e., birds/m^2), higher stocking density refers to more animals within a unit of space, resulting in less space for each animal.

Space Allowance

Space allowance is expressed as the amount of space available per animal (i.e., cm^2/bird). In this case, higher space allowance represents more space per animal.

Group Size

Group size refers to the number of animals within a given group. This could be the number of animals in each cage, pen, or even within a section of a barn. For example, a barn with enriched cages with 30 hens in each cage means that the group size is 30. In an aviary where the barn is divided into 4 rows with 4000 birds in each row, the group size is 4000.

INTRODUCTION

The rearing of pullets is a critical time for development that has significant effects on the long-term health, productivity, and welfare of adult hens (Casey-Trott et al., 2017; Gunnarson et al., 2000; Janczak & Riber, 2015), and space allowance is an important aspect of rearing management. There is a lack of quality research that provides direct results of the effect of space allowance in non-cage systems and, in particular, multi-tier systems on various welfare indicators. This review will discuss the available research on how different floor space allowances impact the biological functioning (e.g., growth, immune function, mortality), affective states (e.g., fear, pain, or indirect measures such as behaviours known to be associated with these states such as aggression or feather pecking) and the ability to express (natural) species-specific behaviours.

The scope of this literature search was to review relevant knowledge of space requirements in layer pullets in multi-tier systems, but some articles on pullets in other housing systems and on adult laying hens were included when considered useful for informing decisions on pullet housing. Searches were conducted using Google Scholar, Web of Science, and OMNI, the University of Guelph Library search tool. Citation mining techniques like the “cited-by” feature in Google Scholar were used to find relevant articles. Keywords/phrases that were used included stocking density, space allowance, aviary, non-cage, enriched, furnished, pullets, laying hens, production, and performance. Search operators like “AND” and “OR” were used to search various spelling of keywords both individually and as a search strings. Literature searches included peer reviewed publications, theses, and scientific opinion articles. Abstracts of search results were sorted by title and abstract, and papers that fit within the scope of this literature search were used.

CHALLENGES OF RESEARCHING SPACE ALLOWANCES

Researching the space needs of poultry and interpreting results can be challenging. This is because determining exact space allowances that promote good welfare is often unrealistic because of the numerous factors that impact welfare and the inconsistencies in methodological approaches (Dawkins, 2018). However, there are techniques for assessing behaviour that inform the space use and needs of poultry. Space allowance needs to accommodate the animals’ physical space (body size), the “dynamic” space that includes the space envelope required for postural changes, and the expression of behaviours. There is a constant balance of social attraction and repulsion forces that influence the interindividual space, representing the desired distance between conspecifics (Keeling, 1995). The preferred interindividual distances between chickens depends on the behaviour that is being expressed (Keeling, 1994). Aspects of behavioural synchrony and clustering in laying hens and pullets were covered in Topic 1.

Varying group sizes can have a significant impact on the behaviour of laying hens and pullets (Keeling et al., 2017). As group size increases, total space as well as free space available for activities increases when animals are kept at constant densities (Widowski et al., 2016). For example, in groups of 10, 20, and 40 pullets housed at a constant rearing density (8 birds/m^2), Liste et al. (2015) found that locomotion increased with group size, largely because of the greater amount of overall pen space available to the birds in the larger groups. Group size influences social behaviour (Keeling et al., 2017) and is a factor that varies considerably throughout the published literature. Group sizes on commercial farms are also variable, and, often, the larger group sizes in commercial aviaries are not comparable to smaller group sizes typically used in research. Differing methodologies can also result in the confounding of group size when testing various space allowances.

PHYSICAL SPACE REQUIREMENTS

Biometric analyses are done to assess physical space requirements. The 2- and 3-dimensional space that an animal takes up when adopting different postures or performing certain movements can be determined using a variety of imaging techniques (Giersberg et al., 2017; Mench & Blatchford, 2014; Riddle et al., 2018; Spindler et al., 2016). Giersberg et al. (2017) reported that the range of body width measurements for 8- to 19-week-old pullets ranged from 10.7–13.96cm and 10.3–13.00cm for brown and white strains of layer pullets, respectively, and suggested these be used when determining perch and feeder space (see Topic 1). Spindler et al. (2013) measured the 2-dimensional (floor area) space occupied by four different strains of pullets from 6 to 18 weeks of age when the birds were standing and sitting. The average areas covered by the different strains at given body weights (BW) at 17/18 weeks of age were: Lohmann Brown (BW 1450g) 422 and 448cm^2; Lohmann Tradition (BW 1500g) 447 and 464cm^2; and Lohmann Selected Leghorn (BW 1300g) 372 and 380cm^2 when standing and sitting, respectively.

Dekalb White (BW 1300g) covered 350cm^2 for standing. Based on these body dimensions, the authors suggested stocking density of 11 to 14 pullets/m^2 for barn (non-cage) systems. For comparison with adult layers, Spindler et al. (2016) found that the average area taken up when standing for Lohmann Brown layer hens is 457.12cm^2 and 397.04cm^2 for LSL layer hens.

Krause & Schrader (2019) suggested a calculation for space allowance for pullets which they adapted from the then existing regulations for laying hens and broiler chickens. The calculation considers body weight, physical space (body area), and the dynamic space required for postural changes and behaviours, which they refer to as "relative additional space." They calculated relative additional space for laying hens and broilers as percentages of the total space requirement (relative additional space = [total space allowance – physical space]/total space allowance) given in the Council Directives for laying hens (1999/74/EC) and broiler chickens (2007/43/EC) as 60% additional space for layer hens and 40% additional space for broilers. For their calculation of pullet space allowance, they assumed that pullets would require the same additional space as broilers. Utilizing a function of body weight to determine physical space occupied when standing for certain strains from Spindler et al. (2013) plus the 40% relative additional space, they recommend a stocking density of 9–15 pullets/m^2. 15 pullets/m^2 translates to 666.6cm^2/pullet. This is the basis for the pullet space recommendation published in the recent EFSA report on the welfare of laying hens (EFSA, 2023).

The biometric data presented above indicates that brown-feathered strains of hens take up more space than white (Giersberg et al. 2017; Spindler et al., 2016). The findings of Kozak et al. (2016a), Kozak et al. (2016b), Pufall et al. (2021), and Rentsch et al. (2023a) show that there are also locomotion and activity differences between white- and brown-feathered strains as well as differences in body conformation that result in variation in the area white- and brown-feathered hens occupy for different movements. For example, Riddle et al. (2018) used digital images of adult hens to determine that Hy-Line Brown and Bovans Brown hens occupied more space during standing, lying, perching, and dustbathing, whereas Dekalb White and Hy-Line W-36 hens occupied more space during wing-flapping when comparing movements across the four strains. The amount of space occupied during standing behaviour was estimated to be 60–100cm^2 (average 89.6cm^2) more/bird for the brown than for the white strains. Additionally, Grebey et al. (2020) found that hens of brown-feathered strains had larger inter-individual distances and needed more litter space for dustbathing than white strains of hens.

BEHAVIOURAL SPACE REQUIREMENTS

Identifying the space that is required for species-specific behaviours can also be used to derive space allowances. The expression of behaviours is affected by a variety of factors, including group size (Keeling et al., 2017), interindividual distance (Riber et al., 2007), and the housing system design and layout of resources (Du et al., 2022; Collins et al., 2011). Regardless of a given space allowance, chickens can be seen clustering or performing synchronous behaviour around certain resources or areas of the barn, resulting in locally high stocking densities in some areas and low densities in others at various times of day.

The EFSA Panel on Animal Health and Animal Welfare developed exploratory mathematical models to extrapolate space allowance requirements for adult laying hens based on the area required for performing selected behavioural needs, for example standing, walking, foraging, dustbathing, wing-flapping (EFSA, 2023). Here they extracted (and sometimes recalculated) data from 10 studies published after 2010 conducted in "improved conditions" where space was not limiting in cage-free or free-range systems. Their models considered the proportion of birds expressing the selected behaviour and the area required to perform that behaviour. Based on a combination of EKE (Expert Knowledge Elicitation) and the results of the behavioural mathematical models, they recommended a space allowance of 2500cm^2/bird for adult laying hens. While the proposed behavioural modelling is a novel approach to estimating space requirements, the following limitations were noted by the authors in their report: depending on the selected behaviour, data were extracted from between only 2 and 8 studies; the various studies used different ethograms when quantifying behaviour; circadian rhythms and behavioural synchrony were not considered; and assumptions regarding interindividual differences may be oversimplified (EFSA, 2023). This approach was not used to estimate space allowances for growing pullets but is provided here for comparison.

LOCOMOTION AND ACTIVITY LEVELS

Activity levels and locomotion of young birds are important for the development of locomotion skills used later in life (Gunnarson et al., 2000; Rentsch et al., 2023b). The ability for pullets to remain active throughout the rearing phase can be affected by the space available to them. As pullets grow, available space decreases when kept at a constant space allowance. Pufall et al. (2021) measured activity levels and locomotion in 14 pullet flocks on 11 commercial farms in Canada with various rearing aviary styles. Stocking densities ranged from 358.76 cm^2/bird to 890.62 cm^2/ bird but were not statistically compared. Authors found an overall decline in walking, running, and aerial behaviours towards end of rearing and suggested the trend of decreased activity and locomotion could be linked to the decrease in available space as pullets grew. However, Kozak et al. (2016a) measured physical activity throughout the rearing period in small custom aviaries where space was not limiting and showed that high intensity activities decreased over the natural course of development. Similarly, Liste et al. (2015) found that pullets spent less time in locomotion and travelled less distance at 15–16 weeks compared to 5–6 weeks of age when housed in pens where space was not limiting. In a recent study on the effects of stocking densities of pullets reared in floor pens without perches, Fischer (2023) observed Lohmann White and Lohmann Brown pullets at two space allowances, 619.1 and 1248.9cm^2/bird. They found that the higher space allowance resulted in more walking and running compared to the low, but these behaviours declined as the pullets aged in both treatments. Similarly, Jensen (2019) found that locomotion was lower when space allowance was decreased through the range of 335–247cm^2/bird in 14-week-old pullets raised in furnished cages. Behavioural differences between pullets and layers might affect their space requirements; pullets may require more space for general locomotion and play behaviour at younger ages compared to older pullets or laying hens.

FEATHER PECKING AND AGGRESSION

Feather pecking is a multi-factorial behaviour problem that causes stress and decreases the welfare of the flock (van Staaveren & Harlander, 2020). Gentle feather pecking involves repeated pecks at the tips of groupmates' feathers without causing damage, whereas severe feather pecking is injurious in that it involves the pecking and pulling out of groupmates' feathers leading to damage to the plumage or integument. Controlling feather pecking during rearing can be critical in reducing its occurrence during the lay period (Bestman et al., 2009; Janczak & Riber, 2015). Aggressive pecking involves pecks delivered to another bird during an agonistic encounter and is usually aimed at the head region. Although aggressive behaviour is considered to be a normal social behaviour that occurs during competition or establishment of dominance relationships, it is undesirable because it can cause stress and injury to the recipient.

Several epidemiological studies investigated the relationship between management factors, including stocking density during rearing and risk of feather pecking and/or poor plumage condition during rearing and/or during lay in non-cage systems. Huber-Eicher & Audigé (1999) studied 64 flocks on non-cage rearing farms with flock sizes ranging from 500 to >9500 pullets. Prevalence of feather pecking during rearing was determined through interviews with the farmers. Flocks reared at a stocking density of >10 birds/m^2 were 6 times more likely to be reported affected by feather pecking. The authors also found that flocks not provided perches were 4 times more likely to develop feather pecking. Bestman et al. (2009) looked at 28 commercial organic pullet flocks that were scored for feather damage during both rearing and lay periods. They found 90% of pullet flocks showing feather damage during rearing also showed feather damage (damaged or missing feathers on the back or tail) during the laying period and that higher stocking density during the first 4 weeks was a risk factor for feather damage. Schwarzer et al. (2022a) measured plumage condition twice during the rearing period and three times during lay in 30 non-beak trimmed flocks on 16 commercial farms. Stocking density during rearing (range 12 to 32 pullet/m^2), as well as poor litter quality, were associated with plumage condition, with birds stocked at higher densities having significantly poorer feather condition in the rearing barn. Additionally, poor feather condition during rearing was a significant risk factor for poor feather condition during lay. Gilani et al. (2013) conducted a longitudinal study in 34 flocks on 29 rearing farms. Feather pecking behaviour and plumage condition were measured at 1, 8, and 16 weeks at the rearing farm and at 35 weeks during lay. Although a number of management factors during rearing were associated with behaviour and feather condition, in contrast to the findings of other studies, stocking density did not significantly influence any of the outcome variables.

There are a few experimental studies on the effects of stocking density on feather pecking during the rearing period. Hansen & Braastad (1994) assessed pecking behaviour and plumage condition in White Leghorn pullets reared in sand pens with perches at stocking densities of 13 and 6.5 pullets/m^2, which was achieved by changing the group sizes in the pens (195 and 390). Behavioural observations performed at 6 and 12 weeks of age indicated that feather pecking was not different at 6 weeks of age, but at 12 weeks the high-density birds feather pecked more. Plumage condition was not different at week 12, but low-density pullets had better tail feathers at week 6. Authors of this study did not differentiate between gentle and severe feather pecks. Nicol et al. (1999) studied aviary-reared laying pullets/hens housed at stocking densities of 30, 22, 14, and 6 birds/m^2 from 14 to 30 weeks (groups sizes of 72, 168, 264, and 368 birds). Gentle feather pecking was highest in the high stocking density, aggressive pecking was highest in the low stocking density (mainly around the nest box), but severe feather pecking was not affected. There was a linear effect of stocking density on feather scores, with the worst feather condition at 30 birds/m^2.

An experimental study performed in a commercial pullet aviary (multi-tier with litter and perches) that housed 100,000 Lohmann Brown layer pullets investigated the effects of stocking density (22.9 vs. 18.1 birds/m^2) and added enrichments on the occurrence of feather pecking and aggressive pecking (Zepp et al., 2018), health and feather condition (Liebers et al., 2019), and the ontogeny of feather pecking during the first 4 weeks of life (Schwarzer et al., 2022b). Over 2 replicate flocks they used 3 experimental groups: high stocking density and no enrichment, low stocking density with added enrichments (pecking blocks and lucerne bales), and high stocking density with enrichments. From behavioural observations conducted throughout rearing, both stocking density groups that contained enrichment showed less feather pecking and less aggressive pecking than the group with high stocking density and no enrichment (Zepp et al., 2018). Severe feather pecking was higher in the high stocking density group compared to low density between the two enrichment groups. Schwarzer et al. (2022b) found a difference in feather pecking with the addition of enrichment, but not with a change in stocking density, up to 4 weeks of age. Liebers et al. (2019) found no effect of stocking density on head injuries or plumage condition across the rearing period.

COMPARISONS OF SPACE ALLOWANCE ON WELFARE INDICATORS

There are very few studies that have directly compared the effects of different space allowances on measures of pullet welfare and performance in aviaries. Therefore, Table 2.1 summarizes methods and results of comparative studies conducted during rearing in non-cage systems (floor pens and multi-tier) and furnished cages containing larger group sizes. Hofmann et al. (2021) reared White Leghorn pullets in floor pens furnished with perches at 23 and 13 birds/m^2 in group sizes of 46 birds to test the effects on behaviour and immune function during the rearing period and determine if any of the effects carried into the laying phase. Blood samples and lymphatic tissue were collected at 16 and 27 weeks of age to examine levels of corticosterone and immune system parameters. Although corticosteroid levels did not differ, heterophil to lymphocyte (H/L) ratio, another indicator of stress, was higher in the high stocking density group, and this persisted into lay during which time the hens were all housed at the same density. There were a number of other indicators of immunological function that differed between treatment groups. Authors also found that preening, foraging, and locomotion, behaviours considered indicators of positive welfare, were lower in high stocking density groups during rearing, and this effect on foraging and preening also continued during lay. Plumage condition was worse in pullets reared at high stocking densities during both rearing and lay. Gast et al. (2022) reared pullets at two stocking densities (reported as space allowances of 374cm^2 and 929cm^2/bird) in separate trials (one density per trial) and measured susceptibility of the birds to become infected by *Salmonella* Enteritidis (SE). Tetra Brown pullets were unvaccinated for SE and orally inoculated with SE at 16 and 19 weeks of age (after moving from rearing pens to an isolation facility at 16 weeks). Organ samples indicated that there was no effect of rearing stocking density on isolation of SE. However, these results should be considered with caution as the densities were applied in separate trials.

Recently, Abraham et al. (2024) measured the effect of two stocking densities (reported as space allowances of 619 and 1249cm^2/bird) on the body weights, body condition, uniformity, and biomarkers of stress in Lohmann Brown and Lohmann White pullets housed in floor. They found that pullets at the lower stocking density had higher bursal weight, which can be an indicator of less stress/better immune function, but they did not find an effect on heterophil:lymphocyte ratio. Uniformity was affected by stocking density in both strains but in opposite directions; improved uniformity was seen at the lower space allowance in white hens and at the higher space allowance for brown hens. Behavioural observations from birds in the same experiment (reported as densities of 13 and 6.5 pullets/m^2) showed that the pullets with more space (1249cm^2/bird) displayed more locomotion, comfort, and exploratory behaviours, which are considered to be indicators of positive welfare, than those at the low space allowance (high SD, 619cm^2/bird) (Fischer, 2023).

Exercise is critical for musculoskeletal development, which could be affected by space available for the animal (Casey-Trott et al., 2017). There are few studies that address the effect of rearing density on skeletal development or performance parameters of layer pullets. Pereira et al. (2021) investigated the effects of rearing space allowance in furnished cages on bone characteristics and eggshell quality during lay. Rearing Lohmann Brown and DeKalb White pullets at either 299cm^2/bird or 247cm^2/bird in large furnished (convertible) cages had no effect on egg production, egg mass, egg weight, or eggshell quality during the laying phase. In terms of bone measures, tibiae were heavier from hens in the 299cm^2/bird group than the 247cm^2/bird group, but tibial and femoral breaking strengths were not affected. Fawcett et al. (2020) also measured musculoskeletal characteristics of pullets reared at different space allowances in furnished cages (closed convertible cages). Dekalb White, Lohmann Brown, and Lohmann Selected Leghorn-Lite pullets were reared in large rearing cages furnished with a platform and perches. Space allowances from 6 weeks to the end of rearing were 247cm^2/bird, 270cm^2/bird, 299cm^2/bird, and 335cm^2/bird, which were achieved by changing group size. Overall musculoskeletal characteristics were unaffected by stocking density except for leg muscles, and the effect was not linear. Additionally, keel bone scoring at the end of rearing and during the late laying period resulted in no differences to stocking density. The authors indicated that this was likely due to providing too high of a stocking density which limited exercise in all of the treatments.

CROWDING AND PILING

Despite providing a desired space allowance, it can be difficult to control for areas of high stocking density resulting from crowding or uneven spacing throughout a barn. The distribution of laying hens throughout an aviary varies and has also been seen to be different between strains (Ali et al., 2016) with crowding often occurring in the litter area (Campbell et al., 2016). Even laying hens in enriched colonies with relatively smaller groups than aviaries showed variations in local stocking densities within certain locations of the cage ranging from 245cm^2/bird to 1109cm^2/bird (Channing et al., 2001). Uneven spacing and varying densities throughout the barn can result in piling and smothering (Winter et al., 2022). Piling and smothering occurs when birds crowd each other so closely that it results in suffocation and can be a major cause of mortality in aviary systems (Mazocco et al., 2024). The exact causes of this behaviour are not known, making it difficult to control, but it is typically seen more in adult hens in cage-free systems with larger group sizes (Grey et al., 2020; Winter et al., 2022). Very little is known about piling during rearing, although Fischer (2023) reported higher odds of piling when pullets were reared at high versus low stocking densities (Table 2.1).

Table 2.1: Methods and results of all comparative studies conducted during rearing in non-cage systems and furnished cages (containing larger group sizes). Behavioural measures include variables likely to reflect negative or positive welfare (see text).

Reference(s)	Life Stage and Housing Environment	Stocking Density (SD) and Conversion			Group Size Range	Behavioural Measures	Biological Measures
		As Reported	in^2/bird	cm^2/bird			
SYSTEM: FLOOR PENS							
Abraham et al. (2024) **Fischer (2023)**	Lohmann Brown and Lohmann LSL-Lite pullets reared in floor pens without perches and sampled between 3 and 12 weeks of age (Abraham et al., 2024) and 8 and 112 days of age (Fischer, 2023)	619 and 1,249cm^2/ bird	95.9 and 193.6	619 and 1,249	59 pullets per pen	Locomotion, comfort and exploratory behaviours were higher in low SD birds High SD birds had higher total feather pecking and were more likely to pile (Fischer, 2023)	No SD effect on footpad, keel tip, or keel fractures Uniformity was improved at lower stocking density for brown and high stocking density for white pullets No differences for most immune system parameters including H:L ratio Low stocking density pullets had heavier bursal weight (Abraham et al., 2024) No effect on mortality (Abraham et al., 2024)
Gast et al. (2022)	Tetra Brown pullets reared in floor pens inoculated with *Salmonella* Enteritidis at 16 and 19 weeks of age	374 and 929cm^2/ bird	58.0 and 144.0	374 and 929	72 pullets per group	Not reported	*Salmonella* Enteritidis isolation from organ samples showed no effect of stocking density for pullets inoculated at 16 or 19 weeks
Hofmann et al. (2021)	Lohmann LSL white pullets were reared in floor pens with addition of perches from 1 to 17 weeks of age. Effects were measured during rearing and subsequent laying phase	23 and 13 birds/m^2	67.4 and 119.2	434.8 and 769.2	46 birds per group	Preening and foraging were lower with high stocking density (both seen during rearing and lay) Locomotion was lower in high SD only during rearing period Worse plumage condition in high SD	H:L higher for high stocking density groups Pullets reared at high stocking density had lower lymphocyte numbers in blood and lymphatic organs No effect of stocking density on CORT concentration

Table 2.1: Methods and results of all comparative studies conducted during rearing in non-cage systems and furnished cages (containing larger group sizes). Behavioural measures include variables likely to reflect negative or positive welfare (see text).

Reference(s)	Life Stage and Housing Environment	Stocking Density (SD) and Conversion			Group Size Range	Behavioural Measures	Biological Measures
		As Reported	in^2/bird	cm^2/bird			
Hansen & Braastad (1994)	White Leghorn pullets reared in sand pens with perches. Data was collected between 6 and 12 weeks of age.	13 and 6.5 pullets/m^2	119.2 and 238.4	769 and 1538	390 and 195 for high and low densities	High SD birds feather pecked more at 12 WOA, however plumage condition did not differ No difference in dustbathing	Mortality and production measures were not affected by stocking density
SYSTEM: MULTI-TIER							
Zepp et al. (2018) **Schwarzer et al. (2022b)** **Liebers et al. (2019)**	Lohmann Brown Classic pullets reared in a commercial aviary with perches. Measures were taken between: – 36–120 days of age (Zepp et al., 2018), – days 1 and 29 (Schwarzer et al., 2022b), and – 5 and 17 weeks of age (Liebers et al., 2019)	22.9 and 18.1 birds/m^2	67.6 and 85.6	436.7 and 552.5	203–230 (until 10th day of life) 101–115 (from 11th day of life)	Enrichments reduced feather pecking, regardless of density Both stocking densities with enrichment showed less feather pecking and aggressive pecking (Zepp et al., 2018) Feather pecking was affected by enrichment but not stocking density (Schwarzer et al., 2022b) No effect of reducing stocking density on head injuries or plumage condition (Liebers et al., 2019)	No effect on body weight or uniformity during the rearing period
SYSTEM: FURNISHED CAGES							
Pereira et al. (2021)	Lohmann Brown and DeKalb White pullets reared at SA treatments in furnished cages from 1–16 weeks of age. Effects were measured during subsequent laying phase	247 and 299cm^2/bird	38.3 and 46.3	247 and 299	91 and 75 birds for low and high	Not reported	No effect on egg production, egg mass, egg weight, or eggshell quality Heavier tibia from high SD

Table 2.1: Methods and results of all comparative studies conducted during rearing in non-cage systems and furnished cages (containing larger group sizes). Behavioural measures include variables likely to reflect negative or positive welfare (see text).

Reference(s)	Life Stage and Housing Environment	Stocking Density (SD) and Conversion			Group Size Range	Behavioural Measures	Biological Measures
		As Reported	in^2/bird	cm^2/bird			
Fawcett et al. (2020) **Jensen (2019)**	DeKalb White, Lohmann Brown, and LSL Lite pullets reared in furnished cages from 1 to 16 weeks of age	247, 270, 299, and 335cm^2/ bird	38.3, 41.9, 46.3, and 51.9	247, 270, 299, and 335	91, 83, 75, 67	Locomotion was lower when space was decreased (Jensen, 2019) More space resulted in more walking and running, which declined with age (Fischer, 2023)	Measurements of muscle and bone development were unaffected by stocking density, except leg muscles were heavier from low SD pullets

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3. MAXIMUM NUMBER OF TIERS IN MULTI-TIER SYSTEMS FOR PULLETS AND LAYING HENS

CONCLUSIONS

1. **There is an absence of studies directly addressing the maximum number of tiers.**
2. **The number of tiers is less important than the means by which birds have the capacity to navigate between tiers and the maximum distance they can fall.**
3. **Chicks, pullets, and laying hens are terrestrial birds and not adept fliers. When flying (flapping-flight) from heights of 150cm or higher, hens require more than 2 meters of landing space/distance. Without this space, the risk of crashing into structures or experiencing steeper, riskier landings increases.**
4. **Chicks, pullets, and laying hens prefer to use navigation aids that allow birds to use their legs to move between levels, and provision of these aids reduces the incidence of injuries in aviaries. Ramps at angles of 45 degrees or less to each other or to the tiers are easier for birds to navigate than ramps with greater angles.**
5. **Birds have more difficulty jumping between diagonally placed perches that are at an angle greater than 45 degrees and between vertically and horizontally placed perches when the distances between perches exceed approximately 75-80cm.**
6. **Frictional properties of surfaces affect the birds' ability to grasp them with their feet.**
7. **Strain, health status, and feather condition can affect hens' and pullets' abilities to successfully navigate a system.**

INTRODUCTION

Chickens kept for egg laying (chicks, pullets, laying hens) were domesticated from jungle fowl, which are a gallinaceous species and are ground-dwelling birds. In a study by Muir (2000), female chicks locomoted using only their legs six to eight hours after hatching, and they preferred to be in contact with horizontal ground while supported by 2 legs. Kozak et al. (2016a) showed that 1 to 9-week-old chicks of 4 common egg-laying strains in a multi-level system spent most of their locomotion time on the ground (52%) and only 1.3% in heights of 71cm to 159cm from the ground. When fleeing on level ground, jungle fowl chicks prefer to walk or run with additional wing assistance (Collias & Collias, 1967), and domestic chicks are observed to do the same in commercial aviaries (Pufall et al., 2021). Adult jungle fowl navigate the environment by spending 70% of their active time foraging while walking on the ground (Collias et al., 1966) and have been shown to prefer nesting near ground level (Krause & Schrader, 2018). When threatened, Galliformes can outrun predators and may use their wings for brief escape flights (Dial & Jackson, 2011) and seek elevation for a variety of reasons, mainly for roosting (Jones & Goth, 2008). When roosting, domestic laying hens were observed to fly to the lowest branch of a tree and, from there, make their way farther up, branch by branch (Wood-Gush & Duncan, 1976). They return by flying directly to the ground (Moinard et al., 2004).

As housing systems for chicks, pullets, and laying hens are becoming increasingly complex, careful consideration of their design is crucial. While multi-tier cage-free aviaries offer freedom of locomotion, they also present challenges. Birds must navigate tiers arranged at various heights greater than their own body height (range of 30.5–41.1cm for Hyline W36 laying hens standing) (Mench & Blatchford, 2014). More specifically, ground birds need to move up and down both in the air (using flapping-flight) and on the ground (using walking, running, jumping) to find essential resources while minimizing the risk for injury (Birn-Jefferey et al., 2014). For laying hens in aviaries, they similarly must find food, water, and nest boxes located on multiple tiers.

In this report, we were tasked with reviewing the existing literature to determine the maximum number of tiers that can be considered adequate for an aviary system from a welfare perspective. While the literature does not suggest a maximum number of tiers for good welfare, various factors within and beyond the bird's biology influence pullets' and hens' ability to navigate vertically complex environments. These factors include, but are not limited to, age (Norman et al., 2018; Kozak et al., 2016b; Rentsch et al., 2023a), strain (Ali et al., 2016; LeBlanc et al., 2018; Pufall et al., 2021; Rentsch et al., 2023a), early life experience (Gunnarson et al., 2000; Colson et al., 2008; Rentsch et al., 2023a), locomotion mechanics (Hong et al., 2024; Leon et al., 2021), health status (LeBlanc et al., 2016), and resource distribution, as well as elements of the housing system itself.

The scope of this review is to compile relevant research that is related to the welfare implications of multi-tier aviary systems. Searches were conducted using Google Scholar, Web of Science, and OMNI, the University of Guelph Library search tool. Citation mining techniques like the "cited-by" feature in Google Scholar were used to find relevant articles. Keywords/phrases that were used included laying hens, pullets, poultry, height, vertical space, tiers, aviary, resource accessibility, multi-tier. Search operators like "AND" and "OR" were used to search various spelling of keywords both individually and as a search string. Although initial searches were conducted using this framework, it was quickly apparent that there was no research that directly addressed the research question. Therefore, relying on its expertise and knowledge, the scientific panel provided a collection of literature with a focus on research on the locomotory abilities of laying hens and the welfare implications of navigating vertical space. Literature searches included peer reviewed publications, theses, and scientific opinion articles. Abstracts of search results were sorted by title and abstract, and papers that fit within the scope of this literature search were used.

DESCRIPTION OF AVIARY HOUSING: MULTIPLE TIERS

The Canadian Code of Practice for the Care and Handling of Pullets and Laying Hens describes a tier as an even, slatted floor with a manure belt underneath, allowing manure to fall through to the belt and improve cleanliness in the aviary system (NFACC, 2017). The maximum number of tiers in an aviary system, including the ground floor, is 4 (NFACC, 2017). Further, the Code specifies that each tier must have a minimum height of 45cm to ensure that hens have adequate space to fully stand.

Tiers in aviaries can be arranged in different ways. For example, shelf-like tiers/even-slatted floors of the same size or pyramidal A-frame structures with tiers/even-slatted floors of various sizes that allow for step-up access to the upper levels. Some aviary designs facilitate navigation within the tier system, while others do so from outside the system. Whether inside or outside the system, aviaries can provide navigation aids to access tiers, such as perches, terraces/platforms, and ramps, which are made of wire, metal, or plastic, with no manure belt underneath. Although perches are primarily arranged and used for resting, they are also strategically placed in aviaries as navigation aids between tiers. Terraces/platforms are arranged between tiers horizontally, allowing birds to jump between tiers. Ramps are inclined surfaces that enable birds to walk or run between tiers.

In 2019, van Staaveren et al. surveyed 33 Canadian pullet farms and found that multi-tier systems ranged from 1 to 3 tiers. van Staaveren et al. (2018) performed a similar study focused on laying hens and found that out of the multi-tier systems surveyed, 36.4% had 2 tiers, 50% had 3, and 13.7% of flocks had more than 3 tiers. Both studies were done between October and December of 2017, prior to implementation of the 2017 Code of Practice for the Care and Handling of Pullets and Laying Hens. Whether farmers included the ground floor in their tier counts was unclear in both studies. Additionally, the minimum requirement of 45cm between tiers (with manure belts underneath, which require space) results in a minimum total system height of roughly 180cm (with 4 tiers). However, the actual height of multi-tier systems will vary based on the specific design used.

NAVIGATING MULTIPLE TIERS

Upward and Downward Movement of Birds on Ramps or Perches

Given chickens' ground-dwelling nature and the substantial height of these systems, aviary/multi-tier navigation can prove challenging. For these birds, moving up along an incline/ramp (uneven surface) involves much greater effort and may be more challenging to control compared to moving on level surfaces. For example, climbing requires additional effort because work must be performed against gravity (Birn-Jeffery & Higham, 2014). Because layer hens are constantly gravid, the challenges they face in climbing are likely to be proportionally higher than for wild birds. Moreover, the proportion of body tissue devoted to reproduction affects their walking kinematics (Rose et al., 2016).

To avoid injury during climbing (Birn-Jeffery et al., 2014), birds prevent uncontrolled movement by using their feet as the first and last contact point with the surface (Pike & Maitland, 2004) while maintaining balance with their wings (Necker, 2006). Surface frictional properties and birds' ability to grasp surface materials with their extremities are essential factors that allow wild and domestic ground birds to securely hold and climb on inclined ramps without sustaining injuries (Birn-Jeffery et al., 2014; LeBlanc et al., 2018).

Given the effort and risk of injury in flying, LeBlanc et al. (2018) tested ramp angles of 0, 20, 30, 40, 50, 60, and 70 degrees to reach platforms at 70 and 160cm heights and showed that both chicks and adult laying hens primarily used walking to climb inclines/ramps of 40 degrees or less. However, for steeper inclines, they employed wing-assisted incline running (WAIR) or aerial ascent. The surface structure, bird's age, and bird's experience impacted their mode of locomotion; however, white-feathered strains exhibited more wing-associated locomotor behaviour compared to brown-feathered strains. Further, inclines/ramps (solid surfaces) were preferred over ladders (gaps between rungs) to climb a tier (Kozak et al., 2016a) in birds from hatch until 9 weeks of age. Similarly, Pettersson et al. (2017a) used British Blacktail pullets at 8 weeks of age and tested them on either grid or ladder ramps of 45 degrees to access a 90cm high structure. They showed that more laying hen pullets successfully navigated across vertical levels to reach a food reward on a grid ramp (plastic slats) over a ladder ramp (wooden rungs). Behaviours measured, such as fewer hesitations, shorter navigation times, and a lower number of attempts, indicated or defined success in this study. LeBlanc et al. (2018) tested birds between 2 and 36 weeks of age and saw that the steepness of the angle achieved during WAIR and the tendency to fly instead of using WAIR increased with age and experience. White-feathered strains exhibited more wing-associated locomotor behaviour than brown-feathered strains. However, some birds were unable to climb inclines greater than 40 degrees, even with WAIR. The authors recommended that inclines/ramps less than 40 degrees be provided in three-dimensional housing systems for steady locomotion, as these can be easily navigated by both chicks and adult chickens without the need for wing use.

There is consensus among the literature that ramps are effective at improving navigation through vertical tiers. Pettersson et al. (2017b) conducted a study on a commercial scale across 16 free-range layer houses housing only brown feathered strains. They looked at birds descending from the first tier of multi-tier and single-tier systems with or without the presence of ramps. Tier heights ranged from 68–89cm across 16 flocks. They showed that birds were more hesitant to descend to the litter from the first tier in multitier aviaries without the use of ramps. Slower descent time in the ramp groups indicated that ramps were used by hens to access the litter. Rentsch et al. (2023a) performed a ramp choice test to observe locomotion strategy for pullets when moving up and down from a 60cm height, or down a 120cm height. The ramps provided for the 60cm were at a 27-degree incline and the ramps for the 120cm were at a 48-degree incline. When ascending to 60cm, aerial locomotion was more commonly used. However, when descending, the ramp was used more than aerial locomotion. Interestingly, this was not the case when descending from 120cm, potentially resulting from increased ramp steepness. Nannoni et al. (2022) tested a control and 3 treatment groups of various structural modifications in a commercial laying hen aviary, 2 of which included the addition of ramps. Behavioural observations showed that the proportion of birds walking was higher in both ramp groups (9.3% and 6.1%) than the non-ramp groups (0.64% and 0.4%). The proportion of flights was also different, showing fewer flights in the ramp groups (90.7% and 93.9%) than the non-ramp groups (99.4% and 99.6%). This suggests that ramps were used when provided, reducing the need for descending flight. Interestingly, this study did not find a difference in falls, collisions, or incorrect landings between the treatment groups. Further, Pullin et al. (2024) reported that fewer than 4% of all vertical transitions were uncontrolled, even though the hens in their study were housed without ramps. In contrast, Stratmann et al. (2015) measured the occurrence of falls and collisions in aviaries with or without navigation aids. Lohmann Selected Leghorn (LSL) laying hens were placed into a 220cm high 4-tier aviary with either a control group or the addition of perches, platforms, or ramps. Although there was no difference between the perch or platform groups, the ramp group experienced 45% fewer falls. More recent, in adult laying hens, ramps were effective in aiding navigation of vertical tiers, as shown by their frequent use in downward transitions, increased transitions immediately after lights on, lower keel bone fracture severity, better feather coverage, and foot health (Toscano et al., 2024).

Perches can also aid in ascent and descent within multi-level systems, though studies of perch use have focused primarily on adult laying hens. Descending has been shown to be more challenging for hens than ascending (Moinard et al., 2004; Scott & Parker, 1994). Further, the size, shape, material, and spacing of perches are critical factors in facilitating navigation (Rufener et al., 2020). Various studies have been conducted on perch location and navigation abilities of different strains of hens (reviewed in EFSA Panel, 2015). In summary, when the distances between perches exceed approximately 75–80cm vertically, horizontally, or diagonally (Moinard et al., 2005; Scott & Parker, 1994; Scott et al., 1997), or when angles exceed 45 degrees (Scott et al., 1997), the risk of poor landings increases, especially at low light intensities (Taylor et al., 2003; Scott et al., 1999). This was confirmed in a recent study by Lambe et al. (2023), where ISA Brown laying hens were more likely to fail to navigate perches set at angles between 45 and 60 degrees.

Upward and Downward Movement in the Air

Wing flapping movements in wild Galliformes are used primarily to escape threats (Tobalske & Dial, 2000). As such, they use high amplitude and high angular velocity wing movements with disproportionally high wingbeat frequencies for their size. However, these vigorous wing movements, combined with high wing loading, reduce their maneuvering proficiency (Tobalske & Dial, 2007). These observations have been confirmed in laying hens in studies evaluating how they manage flapping-flight when descending/moving down to the ground from a 1.5-meter platform. Analysis of hens' flight trajectories showed they had extremely high horizontal acceleration, indicating that they were at the limit of their ability to control their flight trajectory. In other words, they were operating at the maximum power output supported by their anatomy and using all of their available energy and muscle power to control their descent (Leon et al., 2021). Leon et al. (2021) showed that average descent velocity was 3.94m/s. This is an important consideration, as repetitive high-stress loading can lead to musculoskeletal injuries (Verheyen et al., 2006) and is especially important to highlight in commercial birds, who have a high prevalence of orthopedic injuries like footpad dermatitis (FPD) and keel bone fractures (KBF). A recent study by van Staaveren et al. (2023) showed that birds with KBF had significantly higher landing velocities and maximum landing forces compared to those with FPD, even when landing from heights of 30cm.

Hong et al. (2024) showed that brown- and white-feathered hens at 21 weeks of age, when jumping and performing flapping flight from a 155cm tall structure, descended at an angle of approximately 33 degrees, landing about 239cm away. The landing distance of 239 was not provided in this study but was derived for this report from a using a tangent function and a right-angled triangle to find the length. In a related study (Marmina, 2022), hens at 37 weeks of age landed approximately 270cm away. This highlights the importance of providing adequate space for hens to descend from higher tiers directly to the ground. The descent distance for hens in a multi-tier system depends on its design and layout. The vertical distance between the floor and the highest tier represents the potential descent distance. Arranging multiple tiers in a pyramid-like structure to allow for gradual descent and prevent birds jumping from the highest point to the floor is important.

BIRD FACTORS THAT AFFECT ABILITY TO LOCOMOTE

There are various factors that affect birds' abilities to navigate in multi-tier systems. Early life development is critical for both physical and cognitive abilities required for complex navigation (Gunnarson et al., 2000; Regmi et al., 2016; Rentsch et al., 2023b). Laying hens reared in complex environments show improved use of multiple tiers than those without (Colson et al., 2008; Pullin et al., 2024; Stratmann et al., 2022). Access to resources on multiple tiers relies/depends on vertical locomotion, which, as previously discussed, can be enhanced by addition of navigational aids. It is important to note, however, that despite the challenge of vertical navigation, laying hens are motivated to reach elevated surfaces, particularly for roosting at night (Olsson & Keeling, 2002; Schrader & Müller, 2009).

Research indicates that locomotion is significantly different between brown- and white-feathered hens (Kozak et al., 2016a; Kozak et al., 2016b; Garant et al., 2022; Rentsch et al., 2023a) and that brown hens use elevated tiers and perches less than white hens (Ali et al., 2016; Ciarelli et al., 2023; Purdum et al., 2020). Additionally, feather condition affects ability to move between levels. Fully feathered white-feathered hens spent more time at the elevated feeder (53.4%) on platforms at a height of 70cm compared to brown-feathered hens (24.0%). Brown-feathered birds preferred the ground. However, white-feathered birds experiencing loss of their flight feathers reduced elevated feeder and nest box use on tiers/platforms, even those at a height of 70cm, when no ramps or perches were available to assist in navigation. This avoidance (jumping up/down; flapping-flight up-down) was likely due to the increased difficulty in accessing these resources without the aid of ramps/perches and their flight feathers (Garant et al., 2022).

The health status of hens affects their ability to navigate successfully. Laying hens with orthopedic injuries (e.g., footpad dermatitis, keel bone injuries) or poor feather cover can have impaired balancing abilities even when resting on perches (LeBlanc et al., 2016).

Conversely, multi-tier systems can also pose a risk of injury (Campbell et al., 2016; Heerkens et al., 2016). For instance, falling from upper tiers, due to poor descent without access to ramps or platforms, correlated to higher incidence of keel bone damage (Stratmann et al., 2015). When landing from heights of 30–170cm, White Lohmann LSL laying hens in an aviary set-up experience forces 2–7 times their own body weight (van Staaveren et al., 2023). Such impacts can hypothetically lead to serious injuries, including fractures, bruising, and trauma.

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