



Management tools to minimise floor eggs

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by D. L. M. Campbell

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Researcher/Author Contact Details

Name: Dana Campbell
Address: Agriculture and Food, CSIRO, Armidale, NSW, 2350
Phone: 02 6776 1347
Email: dana.campbell@csiro.au

In submitting this report, the researcher has agreed to Australian Eggs Limited publishing this material in its edited form.

Australian Eggs Limited Contact Details:

Australian Eggs Limited
A.B.N: 66 102 859 585
Suite 6.02, Level 6, 132 Arthur St
North Sydney NSW 2060

Phone: 02 9409 6999
Fax: 02 9954 3133
Email: research@australianeggs.org
Website: www.australianeggs.org.au

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Foreword

This project was conducted to understand management strategies that may prevent floor laying behaviour. Floor eggs are a common problem for laying hens in loose-housed production systems both within Australia and internationally. The causes of floor eggs and methods for prevention are still not well understood but are of significant financial cost to industry through lost sales and/or increased labour. Floor eggs continue to be a problem for industry, although the extent of floor laying may vary among farms, production systems, and flocks. Floor laying can result in a food safety issue, putting farms at risk of causing human health problems. Understanding factors that can affect the development of floor laying behaviour and compiling strategies that can prevent its development will aid producers in minimising this issue in their flocks.

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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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About the Author

Dana Campbell is a Senior Research Scientist within the Animal Welfare Project Team of CSIRO, based in Armidale, NSW. She has a background in behavioural ecology and has worked with livestock species over the past 10 years. She has an interest in understanding how individual animals adapt to different types of housing systems and factors that can affect their behaviour and welfare. She has a particular interest in how to improve management of laying hens to optimise their welfare and system performance.

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Executive Summary

Floor eggs can be a common problem for laying and breeder hens in loose-housed production systems. This is where hens lay eggs outside of the nest box, on the litter floor, slats, or tiered wire system. The causes of floor eggs are multifactorial, which can make preventing floor eggs challenging and result in significant financial loss for egg producers. To better understand how floor eggs may be avoided, this literature review compiled information on factors that can affect the propensity of hens to floor lay and management strategies that may prevent the undesirable behaviour from developing. The review included studies on factors affecting nest box use, genetic factors, rearing and early training factors, production cycle factors, and new technologies being developed for floor laying detection and management. The information available online in producer-aimed management documents was also compiled, and ten producers within Australia were interviewed to understand current practices implemented in industry.

Combining the current knowledge from multiple sources, it was apparent that floor eggs are manageable if the right strategies are implemented during the rearing period and when the birds first start laying their eggs. This would be more challenging for egg producers that do not rear their own birds but purchase them just before laying commences. However, understanding the behaviour and needs of a particular hen strain or a particular flock is important given the multiple factors that can influence floor laying development. Floor laying may still develop if all causative factors are unable to be addressed.

Overall Conclusions

The development of floor eggs is multifactorial and can be affected by the hen strain as well as individual hen preferences. Specific strains of hens may be best suited to particular housing system designs. The occurrence of the behaviour can vary across flocks in the same housing system, which means a good understanding of bird behaviour is critical for optimal management of the undesirable behaviour. However, there are common themes and strategies for management that can be considered for minimising mislaid eggs:

- The rearing period is critical for training pullets to travel upwards. Perches, elevated tiers, or rearing like-to-like will improve pullets' physical and behavioural development.
- The pullets need time to learn the laying housing system before they come into lay; transfer before 16 weeks may aid in this.
- The period following transfer is critical for ensuring the birds are learning to move up off the floor and into the system to access the nest box.
- Labour investment when the birds first start laying to keep them up off the floor will prevent floor laying from becoming established in the flock.
- The nest box needs to be the only comfortable, quiet, enclosed place for the hen to lay her eggs.
- Nest box use can be affected by individual hen preferences as well as social factors in the flock.
- Placement of feeders and drinkers should not make nest access difficult nor encourage more hens onto the litter, particularly during the morning egg-laying period. Feed times should not coincide directly with oviposition times.
- New technologies may assist with detecting and managing floor laying, but good labour investment by knowledgeable staff can result in negligible floor egg percentages.

Preventing floor laying from developing is critical, as once the behaviour is established in a flock there is very little (or nothing) that can be done to change this.

1 Introduction

Floor egg laying, 'mis-laid eggs', or 'system eggs' by both domestic egg laying hens and (meat chicken and layer) breeder birds is currently (still) an industry problem. This undesirable behaviour is where the eggs are not laid in the nest box in loose-housed systems but are laid on the litter floor, slatted floor, or tiered wire instead. This behaviour is an issue because eggs laid outside the nest box result in contamination and food safety concerns, with reduced saleability of eggs, broken eggs, increased labour for collection, and ultimately significant economic loss (van Horne 1996; Jones et al. 2015). Floor egg laying is variable in its prevalence and often unpredictable in occurrence with variation across systems, farms, flocks, and pens of the same flock (Mirosh et al. 1986; Appleby et al. 1988a; van Horne 1996; Abrahamsson & Tauson 1998; Heerkens et al. 2015; Steinfeldt & Nielsen 2015; Stratmann et al. 2016), but it is not a new problem. The last comprehensive literature review on the topic of floor laying was published in 1984 (Appleby 1984) and this included stated reports of floor egg occurrence early in the 20th century (Pearl & Surface 1909 as cited in Appleby 1984) highlighting the longevity of this undesirable hen behaviour. At the time of the Appleby (1984) publication, several factors were proposed to relate to floor laying occurrence, although it was noted that "there have been few properly conducted, statistically acceptable experiments on this subject" (Appleby 1984). Factors discussed to affect the prevalence of floor laying were multifactorial and included genetic effects (i.e. strain differences), design and management of the housing system, design and management of the nest boxes, bird training, and rearing influences (Appleby 1984). It was concluded that although there may not be a multitude of systematic studies, when combined with commercial experiences, influencing factors had been substantially considered except potentially the rearing influences (Appleby 1984).

The results presented in the Appleby (1984) review provided valuable guidance on what factors and/or management strategies may be successful in minimising floor egg laying in loose-housed systems. As a general overview, the review stated that genetic strain was indicated to affect both pre-laying and perching behaviour, which can then affect access to and use of available nest boxes. When the hens are first moved to the laying facility, management measures should be implemented to train the birds to go to the nest boxes and prevent floor laying becoming established among the birds. This included disturbing hens sitting on the floor, immediately removing laid floor eggs, and destroying any nests found on the ground. Hens could also be picked up and placed into the nests or be temporarily confined within the nests. But some of these strategies may not be feasible in flocks of large size. Experience in perching/reaching elevated areas was indicated to be important for then accessing nest boxes in the laying facility. Thus, the absence of perches during rearing would negatively impact on the perching behaviour of the adult birds. As pullets typically do not have access to nest boxes during the rearing period, transfer to the laying facility must occur before the birds come into lay (Appleby 1984).

Nest box accessibility and attractiveness were stated as key factors in whether hens will use them (Appleby 1984). There must be sufficient nest boxes available per bird, travel distances to reach the nest box must not be large, and access should not be obstructed by other parts of the housing structure. The nest box must also be more attractive/comfortable than alternative areas such as the floor. It was difficult to draw conclusions about the specifics of optimal nest box design given that studies assessing nest boxes often varied in multiple respects. Research results also varied on whether curtains were preferred or not, or whether hens do indeed prefer dark and secluded nest boxes or not, and whether different types of nesting substrates/materials were present (e.g. wire floor, mats, litter). Preferences may also depend on hen individuality, thus a choice of nest box types could be a potential solution. Nest box use may increase if there are eggs already laid in them, including using decoy eggs, but there were no scientific studies on this management method. To deter birds from the floor, electric wires could prevent the use of favourable floor laying spots. There may also be impacts of lighting and ventilation, where increased overhead lighting could reduce floor laying, but limited systematic studies

were available. Limiting feeding during peak laying times would reduce any conflict between eating and nesting behaviour during the period of oviposition (Appleby 1984).

Almost 40 years following this review, floor egg laying remains a significant issue within the industry, but not for everyone. Some producers state they have solved the problem in their flocks with floor laying reduced to negligible proportions (see Section 4, Producer interviews). Given this is still an issue, but may be manageable, the aim of this non-systematic review is to summarise research on floor laying management in hens (domestic egg layer, their breeders, or meat chicken breeders) that has been published since the Appleby (1984) review. The terms 'floor', 'mislaid', and 'system' eggs are used throughout the review depending on the relevance of the term to the research being cited as all terms are indicative of non-nest box laying. The review examines literature related to factors that affect floor laying including the nest box, genetics, rearing and training, production cycle management and technology development to aid in floor egg management in loose-housed systems. In addition to the scientific literature, the management recommendations that are available online in producer-aimed documents have been compiled to draw on the knowledge that exists within the collective industry experience. Finally, the summarised outcomes of interviews with laying hen producers in Australia about the management strategies that they implement for preventing floor egg laying are included.

2 Factors affecting floor laying

2.1 Nest box factors

Mislaid eggs can be viewed in different ways. This undesirable laying behaviour can result from a lack of interest and motivation to access the nest box, active avoidance of the nest box because it is not an appealing laying site or an active preference to lay on the littered ground. Thus, floor eggs could be managed by both reducing litter attractiveness while increasing nest box attractiveness. The following examines the evidence around factors affecting nest preferences in both laying hens and meat chicken breeders in loose-housed and furnished cage systems. The literature around furnished cage systems is included, as preferred features of nest boxes in this system may be relevant for similarly designed nest boxes in loose housing.

Evidence clearly demonstrates that nests are important to laying hens to fulfill their natural nesting behaviour and that regardless of prior nesting experience, hens are highly motivated and willing to pay a price such as squeezing through small gaps to access a nest site (reviewed in Weeks & Nicol 2006; Cronin et al. 2012; Hemsworth & Edwards 2020). Hens will exhibit pre-laying behaviour typically 1–2 h before they lay. This behavioural change comprises increased activity to search for a nest site, sitting on the site and engaging in nest building behaviour (reviewed in Cooper & Albentosa 2003; Hemsworth & Edwards 2020). While domestic hens have predominantly lost their broodiness, they will still exhibit this pre-lay behaviour and generally prefer discrete, enclosed spaces to lay their eggs in (Weeks & Nicol 2006). Denying nest access will result in behaviours indicative of frustration although there is limited supporting evidence that a physiological stress response is induced in the absence of a nest box (reviewed in Hemsworth & Edwards 2020). Hens may also exhibit frustration behaviours if they are unable to locate a suitable nesting site during the pre-lay phase. In an experimental free range setting, hens were kept in litter floor pens without nest access until 21 weeks of age following which they were given pasture access with potential natural vegetation nest sites (Kruschwitz et al. 2008). The birds were already laying at this age and exhibited frustration behaviours when laying in the pasture compared with those hens that had access to enclosure in the pasture area containing a familiar litter laying substrate (Kruschwitz et al. 2008). Similarly, Freire et al. (1996) observed some components of pre-laying behaviour to increase when hens were presented with a more unfavourable nest option (Freire et al. 1996). Nest type and hen preferences can affect the eventual choice of the nest for laying their eggs, and/or their exhibition of pre-lay behaviour (Struelens et al. 2008; Lentfer et al. 2011).

Not all hens will lay inside a nest box initially, indicating there is an experiential component for increased nest box use across age; however, some hens will never lay in a nest box (Appleby et al. 1988a; Appleby et al. 1988b; Sherwin and Nicol, 1993a; Cooper and Appleby, 1996; Bestman and Wagenaar, 2014; Oliveira et al. 2019). There are differences observed in pre-laying behaviour between nest box and floor layers suggesting there may be inherently different types of laying hens with consistent preferences for litter or a nest box, different perceptions of a nest box, and/or possibly avoidance of a nest box (Rietveld-Piepers et al. 1985; Appleby et al. 1986; Cooper & Appleby 1996; Cooper & Appleby 1997; Cronin et al. 2005; Kruschwitz et al. 2008; Zupan et al. 2008). Behavioural differences in pre-lay behaviour have also been observed between nest and scratch area layers in furnished cages (Hunniford & Widowski 2016). Hens that consistently preferred to lay in a litter tray versus a nest box in individual floor pens exerted the same amount of effort against weighted doors to access the litter tray as those that accessed the nest box (Kruschwitz et al. 2008).

As distinct behavioural types, nest and floor layers are typically conservative in their relative location preferences, and this may extend to the level of the individual for both location and other nest box features. In both commercial and small-scale experimental settings, there was some, but limited

consistency observed in using a particular individual nest box repeatedly in floor-housed birds (Appleby & McRae 1986; Rietveld-Piepers et al. 1985; Appleby et al. 1986). Other research has found high consistency in choice of a particular nest box when there was a choice of two nest boxes in a furnished cage (Wall et al. 2004). Individual meat chicken breeder hens, while not consistent in their use of a particular nest box, were consistent in their choice of features of a nest box when there was heterogeneity in what was available (e.g. height of nest box from the ground; Appleby et al. 1986). When single and triple nest boxes were moved to different positions in the floor pen, individual hens varied in whether they kept picking the same laying location, or same degree of laying isolation (Riber & Nielsen 2013). Hens given a choice between a preferred nest height (i.e. ground level) or a nest in a familiar location, picked the familiar location (Krause & Schrader 2018). This highlights how certain features may be preferred over others and can depend on the individual hen. Thus, similar to research showing that hens vary in their use of different areas within a housing system (e.g. inside/outside in a free range system: Campbell et al. 2020; tiers and litter area of an aviary system: Campbell et al. 2016), variation in nest box choice options within a commercial system may better cater to all hens (Petherick et al. 1993; Sherwin & Nicol 1993b).

Given the laying preferences that individual hens develop, once this preference is established, it may be difficult to modify it and/or there will be a period of significant disruption while hens adapt to a new nest. Individual hens in wire-floor cages with a laying preference for 10 weeks did not modify that preference when a preferable artificial turf substrate was added to a different part of the cage (Hughes 1993). In commercial aviaries, moving the nests from being integrated to against the wall and vice versa resulted in almost all eggs being laid on the litter following the change (Lentfer et al. 2008). The hens showed behaviours indicative of agitation/frustration although there was eventual adaptation to the change (Lentfer et al. 2008). Sherwin and Nicol (1994) showed some hens continued laying in the same location regardless of changes in floor substrate type in individual cages, whereas others changed location to lay on a preferred flooring type. Similarly, Riber and Nielsen (2013) showed hens changed their preferred nest box when the astroturf mat was removed, leaving only wire flooring.

If hens are able to establish a preference for the nest box during the early laying period and the nest box features/microclimate remain consistent, then the preference should be set for the flock cycle. Thus, it is important to ensure the nest box available in the laying system is going to be perceived positively and utilised well (Buchwalder & Fröhlich 2011). Some commercial nest box designs have resulted in higher nest box smothers than others indicating that if the design is not optimal, then there can be other negative behavioural consequences besides floor laying (Rayner et al. 2016). There are multiple nest box design factors that have been shown to affect pre-laying behaviour, nest choice and preferences of laying hens and meat chicken breeder hens. For example, the colour of curtains, the nest box, and nest pad (Brake 1993; Huber-Eicher 2004; Clausen & Riber 2012; Pillan et al. 2023), which may even be influenced by the colour and light intensity experiences of the chicks (Huber-Eicher 2004; Zupan et al. 2007). Preferences for the slope of the nest floor (Stämpfli et al. 2011), presence of curtains (Struelens et al. 2005; Struelens et al. 2008; Hunniford & Widowski 2018; Sun et al. 2023); curtain design (single or multiple pieces) (Stämpfli et al. 2012), construction material of the nest (Holcman et al. 2007; van den Oever et al. 2020a), nest size (Ringgenberg et al. 2014; Ringgenberg et al. 2015a), nest height (Krause & Schrader 2018), and nesting/floor substrate type and/or depth (Appleby et al. 1988c; Petherick et al. 1993; Wall et al. 2002; Struelens et al. 2005; Struelens et al. 2008; Guinebretière et al. 2012) have also been investigated. Preferences may be relative to what is available, and some features may be weighted over others. Hens will show preferences for artificial turf over wire (Hughes 1993; Struelens et al. 2005) but manipulable substrates over fixed flooring types when given that choice (Brake 1985; Huber et al. 1985). Hens prefer a manipulable substrate in the nest, where an open litter box was the most preferred nest choice when compared with a nest with roof and three walls and a thin plastic mat on the floor (Buchwalder & Fröhlich 2011). However, when a curtain was added to the front of this nest, the hens then preferred it over the open litter box, indicating a fully enclosed space may be more important than the laying substrate (Buchwalder & Fröhlich 2011).

Similarly, hens in furnished cages showed preferences for different flooring types, dependent on whether the nest was also enclosed or open, with an enclosed space more valued than substrate type (Hunniford et al. 2018). There may also be factors beyond the nest itself that affect how it is perceived and used in a commercial system. This can include where the nests are placed – either integrated into the tiered aviary unit or separate against the opposite wall, the width and material of the access platform in front of the nests (Lentfer et al. 2011; Stämpfli et al. 2013), and the placement of drinker lines in relation to the nests (Lentfer et al. 2013).

An individual hen may have preferences for a nesting site but, given that hens are housed with hundreds or thousands of other individuals, there are social factors that will also be influencing where a hen will lay. Rietveld-Piepers et al. (1985) showed no effect of social dominance status on floor or nest laying. However, other research has suggested subordinate hens may be excluded from nest access leaving only the floor as a laying option (Holcman et al. 2007). There can be competition for the more preferred/popular nesting sites and pecking aggression may affect nesting behaviour. Observations of nesting in nest boxes and corners of experimental floor pens with different (small) flock sizes showed corners were preferred laying spots despite there being greater competition for these areas in the larger flock sizes including more aggressive pecks (Lundberg & Keeling 1999). However, if a bird was getting pecked at, she stayed at the site for a shorter amount of time, and those birds delivering the pecks stayed in the corners for longer, highlighting the impact of social variables on the time that a hen may spend at a particular nesting site (Lundberg & Keeling 1999). In an experimental testing scenario, hens were less willing to enter a corridor to access a nest box when there was an unfamiliar or dominant bird present relative to a subordinate, or no conspecific, and they tried to find alternative routes to access the nest (Freire et al. 1997).

A key social factor beyond dominance ranking in laying hen nesting in commercial systems is gregarious nesting where a hen is more likely to occupy an already-occupied nest (Riber 2010). This may increase the risk of smothering in the nest, heat stress, scratch/peck wounds, as well as affecting egg quality (more broken and dirty eggs) and increasing floor eggs (Riber 2010; van den Oever et al. 2021a). The propensity for this behaviour in domestic hens varies between individuals (Sherwin & Nicol 1993a; Tahamtani et al. 2018). It also contrasts with isolated nesting seen in the hens' wild counterparts (Riber 2012a). Domestic strains allowed free choice for varying nest sites (natural or artificial opportunities presented via vegetation and plywood sheets) in a semi-natural setting still showed gregarious nesting behaviour (Riber 2012b). This may, in part, have been affected by nest site options as gregariousness was only observed in nests along enclosure borders, which were presumably the more preferred nesting sites versus those nesting sites 1 m+ away from the border (Riber 2012b). Gregarious nesting may be derived from an anti-predator response to nest predation (Riber 2012a). Although research with small groups of hens found no relationship between fearfulness, nor sociality, or dominance on whether hens tended to be solitary or gregarious nesters (or a mix between both) (Tahamtani et al. 2018).

Gregarious nesting may be affected by the age of hens and their experience in selecting their own nest site where inexperienced hens may be more likely to visit already occupied nest sites (Riber 2010). This may, in turn, contribute to the higher use of particular nest boxes within systems that are typically corner or end nest boxes or particular sides of nest boxes (Riber 2010; Clausen & Riber 2012; Riber & Nielsen 2013; Ringgenberg et al. 2015b; Villanueva et al. 2017; Li et al. 2018). Alternatively, a specific attractive nest box can increase the observed gregarious nesting (Clausen & Riber 2012; Giersberg et al. 2019). Meat chicken breeder hens have been shown to crowd in highly preferred nests resulting in greater aggression (van den Oever et al. 2020a). If a system is to provide heterogeneity in nest boxes to try and minimise crowding in specific boxes, then it is suggested that modifications to less preferred middle nest locations may improve nest occupancy uniformity (Clausen & Riber, 2012). However, trials with variation in nest curtain colour and identifying symbols did not affect nest visits in experimental floor pens relative to other factors such as nest position and occupancy (Ringgenberg et al. 2015b). To

ensure sufficient nesting space for hens in commercial loose-housed systems, colony nest boxes are often large. This may decrease the hens' preference for the nest box, as testing with smaller numbers of hens in floor pens showed a preference to lay more eggs in smaller sized nests (i.e. larger colony nests with dividers) compared with the more open space of the typical commercial colony nest (Ringgenberg et al. 2014; Ringgenberg et al. 2015a; Zheng et al. 2018). Ensuring the nest box is optimally attractive is challenging as there are multiple design-related and social factors to consider.

2.2 Genetic factors

The original floor egg laying review indicated behavioural differences between hen strains that contributed to the occurrence of floor eggs (Appleby 1984). This effect of genetic line, particularly brown versus white hens, has been evidenced across several further studies but with contradiction in whether the research finds that white or brown hens tend to lay more floor or system eggs (Campo et al. 2007; Singh et al. 2009; Heerkens et al. 2016; Villanueva et al. 2017; Purdum et al. 2020; Rizzi 2020; Farkas et al. 2022; but see van den Oever et al. 2020b for no differences in floor egg laying across different meat chicken breeder genetic lines). In alignment with these differences in laying behaviour, there is evidence of the variation between white and brown hens in how they use a tiered aviary system, including the nest box (Ali et al. 2016; Villanueva et al. 2017; Ali et al. 2019a; Ali et al. 2020; Purdum et al. 2020). This in turn, has an impact on whether eggs are laid in the nest box, the wire flooring within the system, or on the litter (Villanueva et al. 2017; Purdum et al. 2020). Brown strains are often heavier than white strains, which may contribute to reduced vertical movement and lower use of perches (Silversides et al. 2012; Purdum et al. 2020). If hens are less motivated to access the upper tier where the nest box is located or spend a greater amount of time on the litter, there is a greater chance of eggs being laid outside the nest box (Ali et al. 2020; Purdum et al. 2020).

White and brown strains have been shown to vary in oviposition timing (Campo et al. 2007; Icken et al. 2012; Villanueva et al. 2017; Bécot et al. 2021). Some research indicates that white strains compared to brown strains will lay most of their eggs within a 3-h window (Icken et al. 2012), whereas other research indicates that the majority of eggs from brown strains are laid within a 4-h window (Villanueva et al. 2017). Brown strains do appear to lay their eggs earlier than white strains (Campo et al. 2007; Icken et al. 2012; Lillpers 1991; Villanueva et al. 2017; Bécot et al. 2021) and brown or white strains vary in duration spent occupying the nest box (Icken et al. 2012). Low to moderate heritabilities have been quantified for time of oviposition and duration of time occupying the nest box (Icken et al. 2013), or moderate to high heritabilities for oviposition time (Lillpers 1991). These genetically pre-determined oviposition times could result in competition for nest box resources at certain times of day contributing to more eggs being mislaid (Villanueva et al. 2017; Ali et al. 2020) and thus selection should maintain individual differences (Bécot et al. 2021). Variation among different strains suggests some strains may perform better in certain types of housing systems or housing system designs (Tauson et al. 1999). System resources should be modified to accommodate strain behavioural variation (Villanueva et al. 2017; Purdum et al. 2020) and calculation of sufficient nest box space needs to consider hen preferences for nest boxes on certain levels only (Farkas et al. 2022).

In addition to differences across genetic lines, there is also evidence that variation in nest preferences, time spent in the nest and floor laying behaviour/nest box acceptance within white and/or brown strains is heritable (Settar et al. 2006; Wolc et al. 2021; Bécot et al. 2021; Bécot et al. 2023) indicating selection against undesirable traits may be possible. Selection for higher numbers of eggs laid in a trap nest across five generations with different hen lines did see a reduction in the percentage of floor eggs (Sørensen et al. 2017). In the breeding environment at the level of genetic selection, those hens that do not produce a higher number of eggs in the nest are selected against, however, the selection is not suggested to be an all-encompassing solution (Preisinger 2018). It may be that there is a genetic component for the ability to learn nest box use which, in part, could be related to perching ability

(Wolc et al. 2021). This suggestion of the relevance of learning ability highlights the importance of adequate rearing and training when the birds are developing and coming into lay, respectively, to prevent floor laying (Preisinger 2018; and see Section 2.3, Rearing and early training related factors).

2.3 Rearing and early training related factors

The Appleby (1984) floor egg laying review highlighted that, at the time, there was comparatively more limited consideration of rearing influences in the management of floor egg laying. To address this gap in knowledge, Appleby et al. (1988b) conducted a study to clearly demonstrate the benefits of perch provision during rearing for reducing floor laying in adult birds, recommending early placement of perches (by at least 4 weeks of age). This was further supported by Gunnarsson et al. (1999) who looked at risk factors for floor eggs across 59 flocks of loose-housed birds on 21 different farms and found the only significant correlating factor to reduce percentages of floor eggs was access to perches no later than 4 weeks of age. Although the authors did highlight that rearing with perch access was not a complete solution to floor eggs and additional factors would still need to be managed (Gunnarsson et al. 1999). Similar effects are seen in meat chicken breeder birds where rearing (from day-old) with perches similar to the nest box perches they would encounter during lay, significantly reduced floor laying when the breeder birds were moved to a slat-litter laying house (Brake 1987). Even provision of perches from 8 weeks of age still reduced floor eggs in breeder flocks during the peak lay period (Appleby et al. 1988b).

There is now a much greater understanding of the short and long-term impacts of rearing environments in how pullets develop physically, physiologically, and behaviourally (Janczak & Riber 2015; Campbell et al. 2019). Generally, there is a recommendation to rear birds in the same type of systems they will be housed in during lay to optimise their adaptation and performance following transfer to the laying facility (Abrahamsson & Tauson 1998; Colson et al. 2008; Janczak & Riber 2015). The like-to-like benefits were demonstrated by Colson et al. (2008) who looked at behaviour and adaptation to (i.e. use of) an aviary system following rearing on the floor (with perches and platforms), or aviary rearing. After transfer to the laying facility at 17 weeks of age, those birds that were floor-reared showed poorer use of the aviary upper levels, with a preference for the litter and lower levels. This preference resulted in fewer eggs laid in the nest box and more laid on the litter across the early-to-peak lay period relative to the birds that had been aviary-reared (Colson et al. 2008). Further evidence for the need to allow hens the opportunity to perch and access vertical structures comes from research looking at the effects of transferring pullets to an aviary at 17 weeks of age, providing them perches and nests in floor pens at 17 weeks of age, or keeping them in floor rearing pens without elevated structures (Ali et al. 2019b; Karcher et al. 2019; MacLachlan et al. 2020). This situation would occur if there was a requirement to delay pullet transfer such as during a disease outbreak. With these treatments in place until 25 weeks of age when all the birds were moved into experimental aviaries, those pullets given vertical structures and nest box access laid fewer floor eggs (Karcher et al. 2019; MacLachlan et al. 2020). This was likely related to the reduced use of the upper levels of the tiered system by floor-reared birds (Ali et al. 2019b). The differences between treatments had lessened by 54 weeks of age, showing the birds could adapt at a later age, but there were still more floor eggs laid by those birds that had no nest box and vertical structure access during the early laying period (MacLachlan et al. 2020). Similarly, an experimental study where birds were transferred at 22 weeks from conventional cage rearing to an aviary system showed over 95% floor laying across the 10-week trial period (Philippe et al. 2020). Other beneficial rearing effects include the use of dark brooders for layer chicks, which mimics the natural brooding environment that a mother hen would provide. Chicks reared with dark brooders in an experimental setting showed fewer floor eggs during the early-to-peak lay period compared to control birds reared in standard open floor litter conditions (Riber & Guzman 2017).

The rearing period before transfer to the laying facility is important for pullets to develop movement skills and familiarity with a system type, but the initial period after transfer to the laying facility is also critical. The exact age at which pullets are transferred varies and can depend on multiple factors such as production shed schedules, pullet vaccination schedules, labour, and the cost of feeding birds not producing eggs. The typical transfer age is around 15–17 weeks. Egg laying then begins around 18+ weeks of age, but hens will start looking for a suitable nest site prior to their first egg (Rietveld-Piepers et al. 1985). This highlights the importance of familiarity with nest box laying locations before oviposition onset to reduce egg laying outside of the nest (Sherwin & Nicol 1993a). There is evidence across multiple studies that nesting behaviour has a learned component where the percentages of floor eggs are typically highest when the hens first start laying and reduce across time (Cooper & Appleby 1996; Settar et al. 2006; Bestman and Wagenaar 2014; Oliveira et al. 2019; Wolc et al. 2021). Thus, varying strategies of training will occur when the birds first move into their production housing. For example, Pillan et al. (2023) showed that the use of nest lights coming on 1.5 h before the main house lights increased nest box use from 17–26 weeks compared to nests without the low intensity lights in an experimental aviary system.

Other management strategies following pullet transfer can include restricting access to litter until the birds have familiarised themselves with the cage portion of the system (i.e. food, water, nest boxes, perches, tiers), litter restriction until the hens have reached peak lay, or continued litter restriction each morning across the lay cycle until the majority of daily eggs have been laid (Nicol et al. 2003; Zhao et al. 2015; Ali et al. 2016; Oliveira et al. 2019). Outdoor access in free range systems is also typically restricted after pullet transfer until laying commences and until after the morning laying period across the production cycle (Rana et al. 2022). However, early work by Mirosh et al. (1986) found exposure to a range area during onset of lay actually decreased floor laying, possibly because the pullets were more motivated to seek out secluded nest areas compared to pullets kept in an enclosed system. Experimental evidence for the impacts of litter restriction is limited. Testing of a two-week litter restriction period upon first transfer to the laying facility showed no impact on percentage of floor eggs across the laying cycle (Alm et al. 2015), but it is unclear if this was compounded by the nest boxes being closed for the first 12 days following transfer until the first egg was laid (Alm et al. 2015). In contrast, partial restriction of litter access each morning across the laying cycle resulted in a significant reduction of floor eggs compared with hens that had continuous litter access (Oliveira et al. 2019). The aviary-reared pullets were transferred to the laying facility at 17 weeks of age and all birds were restricted to the tiered portion of the system for 10 days to learn the placement of resources, including the nest box (Oliveira et al. 2019). The hens that were given partial litter access had a total of four weeks before litter access was allowed, compared with only 10 days restriction for the comparative continual litter access treatment groups (Oliveira et al. 2019). It is likely the initial longer period of litter restriction trained the birds to lay in the nests with this reinforced by the continual partial restriction across the flock cycle. Although litter restriction is implemented by producers to avoid a mislaid egg problem (Palczynski et al. 2016), the restriction can be a risk factor for feather pecking (Nicol et al. 2003; Lambton et al. 2010), highlighting the management balance that producers have to work by to mitigate multiple undesirable hen behaviours (Palczynski et al. 2016).

2.4 Production cycle factors

While there are different management strategies that can be applied during rearing and early lay to prevent floor laying, it is generally understood that if floor laying is established in the flock, there are few options for remedying this. However, there may be factors of the adult hen laying system housing design that contribute to floor egg percentages. For example, increased floor laying may be a consequence of the system type; free range compared with deep litter (Campo et al. 2007), or of structural housing system design, such as the specific type of aviary system in place (Stratmann et al. 2016). Housing design modifications may also impact floor egg laying. In experimental testing

conditions, meat chicken breeder birds reared with perches and platforms were given access to floor pens that either did or did not include a raised slatted area in front of the nest box, and the slatted area decreased floor eggs (van den Oever et al. 2021b). The drinker nipples were also up on the slatted area, which may have encouraged the birds to go up to the nest boxes (van den Oever et al. 2021b). Comparatively, in the treatment with no slats the drinker lines and nest boxes were in the litter area (van den Oever et al. 2021b). In contrast, Stratmann et al. (2015) found no effect of additional ramps, perches, or platforms in an aviary system for aviary-reared birds on the percentages of floor eggs. Modifications of aviary design to facilitate greater movement around the aviary (inclusion of ramps and/or removal of internal partitioning panels) also did not affect the percentages of mislaid eggs (Nannoni et al. 2022). However, it was observed in one of the treatment modifications that the highest concentration of eggs laid on a particular aviary tier did equate to the highest proportion of system eggs, suggesting possible nest space competition (Nannoni et al. 2022). Increased stocking density can increase floor eggs, likely also a result of greater nest space competition (Kang et al. 2016). Perches provided during the laying period in a free range system for birds that had been reared with perches had no impact on the percentage of floor eggs relative to perch-reared birds without specific aerial perch access during lay (birds still perched on water lines and feeders) (Donaldson & O'Connell 2012). As discussed previously (see Section 2.2, Genetic factors), floor laying may be a consequence of the strain of hen being housed and an interaction of housing design with strain behaviour. Heerkens et al. (2016) found inconsistent strain-dependent effects of additional ramps in experimental aviary-style systems for reducing floor eggs.

There are a small number of research studies that have looked at manipulating factors across the laying period to either directly or indirectly look at the impacts on floor laying. Inclusion of 1.5% of experienced hens in an aviary system during the laying period did not affect the percentages of floor eggs, but it was not clear from the study if this was a result of the (low) density of experienced hens or that they did not have influence on the younger (aviary-reared) hens' behaviour (Oliveira et al. 2019). Environmental enrichment of hay provided across a flock cycle in aviary systems significantly reduced the percentage of mislaid eggs although the numerical difference was small, as mean mislaying percentages overall were only around 1% (Son et al. 2022). In contrast, Schreiter et al. (2020) found the provision of pecking stones and alfalfa bales both during rearing and lay increased the percentage of floor eggs, which the authors suggested may have, in part, been due to increased time spent on the litter area using the enrichments (time on litter was not explicitly measured). Finally, van den Oever (2020b) looked at health-related factors across five meat chicken breeder genetic lines but found no relationship between hock and footpad contact dermatitis and floor egg laying, indicating the behaviour was not a direct result of mobility differences. Overall, research across the laying period is limited as the key periods for behavioural manipulation are when the birds are younger.

3 Technology advancements

With the increase in precision technology for agricultural management, there are considerations of how advanced technologies could help prevent and/or manage floor eggs (Ren et al. 2020; Subedi et al. 2023). Floor robots are commercially available (e.g. Spoutnic, T-Moov) to encourage hens to move off the floor rather than establish litter nests and floor laying behaviour. This may help to train the hens to use the nest boxes initially, replacing or complementing frequent house walk-throughs during this period. However robust evidence of their effectiveness in the literature is currently limited (Li et al. 2022). There may be some effect to reduce floor laying, but hens do rapidly acclimate to the robot and can be observed riding on it after a couple of weeks (Li et al. 2022). Several different robots for floor egg detection and collection have also been the subject of precision technology development (Ren et al. 2020). These have shown varying degrees of egg harvesting success for potential reduction in the labour requirements when there is a floor egg issue across the production cycle (Vroegindeweij et al. 2014; Joffe & Usher 2017; Usher et al. 2017; Vroegindeweij et al. 2018; Li et al. 2021). These robots contain camera-based automated algorithms for egg detection with varying egg pickup techniques (e.g. suction cup, gripper, helical spring), and movement trajectory algorithms spanning the entire floor area including frequent visits to high-risk areas (Vroegindeweij et al. 2014; Joffe & Usher, 2017; Li et al. 2021). Sensors within the robots enable navigation among birds and other obstacles in the complexity of cage-free environments (Usher et al. 2017; Vroegindeweij et al. 2018; Chang et al. 2020). There is still research into further refining and validating detection algorithms (Li et al. 2020).

Ongoing research includes the possibility of automatically detecting hens sitting on the ground (particularly in corners) indicative of floor egg laying behaviour (Bist et al. 2023) and fixed camera detection systems that can automatically monitor floor eggs within the house using machine vision (Subedi et al. 2023). It is anticipated that this type of technology could be valuable as a training tool when production commences, to remove the eggs and not attract other hens to floor lay, as well as across the production cycle if the floor laying persists, to reduce labour requirements. Ultimately, radio-frequency identification-enabled smart nest boxes that can track an individual hen's laying behaviour may allow producers to detect poorly performing birds, at the very least and improvements in nest box technology may facilitate genetic selection and research at the individual hen level (Chien & Chen 2018).

4 Producer interviews

To collate the industry knowledge about floor egg management that is not captured in the scientific literature, semi-structured interviews were conducted with 10 egg laying hen producers in Australia (approval via CSIRO's Social Science Human Research Ethics Committee in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018): Approval number 015/23). Thirty-five producers (or former producers now working as technical poultry consultants) were initially contacted (by phone call, email, or website contact form) and invited to participate by providing a short summary of the study aims, the topic areas of the questions, expected time commitment, and assurance that all answers would be compiled anonymously following participation.

A total of 10 producers (8 primary producers and 2 technical poultry consultants) agreed to be interviewed and voice-recorded, and were provided the human ethics participant information sheet prior to the interview. A series of 10 questions was asked in a qualitative conversation style commencing with questions about years of experience in hen management, the type of housing system they work with, the hen strain they house, typical flock size, and the type of nest boxes. The producers were also asked whether they rear their own pullets or if they buy them in, and if yes to the latter, how much knowledge and control do they have over the rearing process. They were then asked if they currently have a floor egg problem, if it varies by flock, and the extent of their problem (i.e. percentage estimate of floor eggs). Whether the answer to the latter question was 'yes', or 'no', all producers were asked what management strategies they implement or have tried to implement to reduce their floor egg problem. This question resulted in the lengthiest answers depending on the depth the interviewee went into with back-and-forth exchange between the interviewer and interviewee allowing the conversation to evolve. Interviewees were asked whether these management strategies were based on trial-and-error, reading literature/online documents, or talking with other producers. Finally, the interview ended with an open-ended question giving the producers a chance to provide any other information they felt was missed by the previous questions. The interviews were voice-recorded and later transcribed for accuracy of data capture with all information gathered by a single researcher (Dana Campbell).

Across the 10 producers, the years of experience managing laying hens ranged from 5 to 40 with a combined total of 162 years of laying hen management. All producers worked with brown strains, but some had experience working with other strain types previously. Every producer currently worked with free range systems, but some also worked with (or had worked with) aviary, barn, and slatted systems. Flock sizes were varied across all producers, ranging from 3000 up to 50,000 birds. Three producers bought their pullets in from contract growers at 16 weeks with no control over how they were reared (these were producers from smaller-sized farms), with the remaining producers either rearing their own or contracting the rearing but with knowledge and control over the rearing process. Nest boxes were all colony and curtained that came with the installed systems. Of the 10 producers, four stated they were not concerned about floor eggs as their management strategies kept the mislaid eggs to a negligible number, the remaining producers indicated they did have a problem, ranging from around one to 15%, with inconsistent variation across flocks. All producers indicated strategies to (try to) manage floor eggs were typically based on trial-and-error, with four producers stating they talked to other producers, four producers read advice online in breeder/housing system manuals, one producer talked with a poultry consultancy company, and two producers read scientific literature.

The management strategies that producers implemented were relatively consistent across all interviewees but were dependent on the labour/financial resources available to producers and the extent of control they had during the bird rearing process. The strategies centred on rearing and early lay training as critical time points for modifying bird behaviour. Generally, the key aspects were making sure you were rearing like-to-like, i.e. if birds were going to be placed in an aviary system at lay, they

needed to be reared in an aviary system so they would know how to go up (to the nest box) at lay. This was feasible for those producers that reared their own birds but less so for producers that were only able to buy in pullets at 16 weeks. These producers expressed frustration at their lack of control over the rearing process. Furthermore, there was uncertainty around the condition in which the pullets may arrive. For example, if there were any issues during the rearing process that would affect the bird behaviour, growth, and adaptability, this was unknown to the receiver at the time of arrival. For those producers that had control over the rearing process, they transferred pullets over to the laying shed earlier than 16 weeks (14–15 weeks) to give them more time to adapt to the laying housing and become familiar with the set-up, including nest box location, prior to first oviposition. While an early transfer (i.e. early buy in of pullets) may partially mitigate lack of control over rearing for smaller producers, it was not economical to do so given the cost of feeding birds that aren't yet laying and/or lack of empty sheds not occupied by hens still laying.

Ramps were used in the laying shed initially by three producers to improve the transition between rearing and laying. Another factor that was stated by every producer interviewed was the importance of floor/shed walks at the beginning of the laying period to keep the birds moving up off the floor into the nest boxes, to pick up eggs laid on the ground, and to ensure that the nest box was the only quiet place for the birds to lay their eggs. Producers stated it wasn't just about doing regular floor walks, but these walks needed to be done by competent staff who knew what the purpose of the walks was and were willing to invest the time and effort to do them properly. Every producer recognised this management investment for the first approximate 6 weeks was critical to establishing good laying behaviour in their birds for the remaining flock cycle. However, three of the smaller producers stated they either could not afford this labour investment as it was more than the financial loss from unsaleable floor eggs, or they could not find enough good staff to complete this job, so they accepted a certain percentage of floor eggs was inevitable. One producer said they were told that larger-scale producers may accept the loss of floor eggs as they could more easily afford to. There was one producer that looked for broody birds during the floor walks and these were culled.

Producers all varied in how they managed the nest boxes, whether they were closed when the birds arrived in the shed to prevent roosting and/or smothering in them, whether they were open to allow the hens to start becoming familiar with them before laying commenced, or whether half were open and half were closed to encourage a more even distribution of nesting. Lighting was mentioned by six of the producers, either nest box lights to train the birds, stages of dimmable lights to encourage birds up off the floor during training, or additional lighting in dim floor areas. Five producers also stated they used electric wires on the shed perimeter and/or feeder and drinker lines to prevent birds from perching where they are not meant to, and to prevent laying in the floor area. One producer had the same electric wire layout in rearing, so the birds learnt early on and were familiar with the wire placement during lay. The electric wires were used predominantly in the training period during early lay. Finally, one producer mentioned the position of the drinker and feeder lines should not be on the litter as it encourages birds to the litter area, and two producers stated feeding times should be controlled so that there is no conflict between feeding and laying during the morning lay period.

5 Producer-aimed online management documents

A Google search was conducted December 2022 with the search terms ‘How to reduce floor egg laying’ and ‘How to prevent floor egg laying’. Websites that were listed across the first 3–4 pages of the search were incorporated, with similar themes observed across most of the articles/online management guides that were read. The management suggestions were related to domestic egg laying hens across different loose-housed systems, meat chicken breeder flocks, and backyard hens. There was similarity in management advice across all types of hen systems. Some guidelines were contradictory, such as whether to open the nest boxes as soon as the hens arrive in the laying facility or keep them closed for a period to encourage curiosity when the birds come into lay and prevent nest box soiling. Additionally, whether electric wires are beneficial (e.g. prevent laying in floor corners) or detrimental (e.g. discourage hens to jump up if placed on water and feeder lines). As a general summary of the management recommendations, rearing is highlighted as important in training the birds to be able to move up and experience similar conditions to what they would during lay. The training period when the birds first arrive in the laying house is also critical to get the birds up to the nest boxes. Regular floor walks are needed when hens start to come into lay and any eggs on the floor must be picked up immediately. The litter area should not be too comfortable (e.g. litter not too deep, lighting not too dim) and nest boxes should not be uncomfortable (e.g., too draughty, too hot, too bright, infested with mites) or difficult to access (e.g. hens crowding outside, other housing structures in the way, too far away from feed/water).

More information is summarised in Table 1, along with source links for each online manual for further details. These factors all align with those documented in a 2018 report based on visits to poultry farms internationally and discussions with poultry experts on the management of floor eggs (O’Flaherty 2019). The key conclusion from the O’Flaherty 2019 Nuffield Scholarship activity, as well as across the online management documents, was that the causes of floor laying are multifactorial but can be sufficiently managed by good stock people. Each flock can be different and thus it is critical to be able to read the birds and adjust management strategies accordingly. It has also been stated in online management guides that despite best practice, the occurrence of and/or extent of floor laying may be due to ‘luck’, indicating that all the causes of this behaviour in a specific flock of birds are not yet known.

Table 1 Summarised online suggestions for floor egg management with original source links indicated (all links last accessed 29 May 2023)

Management suggestions to prevent/reduce floor laying; risk factors for floor laying occurring

<https://www.val-co.com/5-tips-prevent-floor-eggs/>

1. Not too much litter so it cannot be made into a nest. ~ 1 inch
2. Give the birds several weeks to adapt to the nest boxes before laying commences.
3. Walk through the house 2–3 times per day for the first 2 weeks of lay to get the hens up off the ground.
4. Collect laid floor eggs frequently.
5. Adequate lighting on the floor so it is not attractive as a dark spot for laying.
6. Adequate nesting space so hens do not compete for room.

<https://www.poultryworld.net/poultry/how-to-prevent-floor-eggs/>

1. Collect laid floor eggs frequently.
2. Adequate training to move between levels. Rearing and laying housing must be similar so hens are familiar with tiered structures.
3. Adequate lighting on the floor so it is not attractive as a dark spot for laying. Eliminate shady spots/dark areas. Dimming (sunrise) in the morning is helpful for hens that lay before the lights come on.
4. Not too much litter so it cannot be made into a nest.
5. Walk through the house 2–3 times per day for the first 2 weeks of lay to get the hens up off the ground. Disturb those hens that are nesting on the ground.
6. Ensure nest boxes are not difficult to access so that birds can easily pass each other when looking for a nest. Resting hens can block the nest box entrances. Perches or a grill in front of the nest boxes enable hens to pass each other and move to an unoccupied nest.
7. Ensure there is no draught in the nest boxes. If it is cold and draughty the hens will not lay in there. An airtight plate under the nest boxes is recommended.
8. The hens will be less attracted to the nest boxes if there is no water available in front of the nest.

<https://www.thepoultrysite.com/articles/minimizing-floor-and-slat-egg-problems>

1. After the first 3–4 weeks of chick rearing, the light intensity should be reduced so that there can be at least a threefold increase in intensity when the hens are going into the production phase. The light needs to be uniform within the layer house. Recommended to have a minimum of 64–86 lux at bird level in the darkest places of the laying facility. Eliminate shadows under the nest boxes as much as possible.
2. When young hens are selecting nest sites, there should not be any possibility of injuring themselves. The young hens should be confident in jumping onto slats. Slats during rearing from 8–10 weeks onwards are recommended for training the birds. Best if they match (design/material) what will be in the production house.
3. Appropriate nest ventilation will ensure the nest area is not too hot or too cold to discourage hens from entering the nests. Nests should not be too far away, so the hens do not have difficulty locating them and do not have to travel long distances to reach them.
4. The type of feeder could affect laying behaviour where birds may lay eggs under pen feeders or if the feeder height is not correct. If feeders are too close to the nests, then

they can restrict easy movement of hens between nests. Feed should be available either at lights on, or after most eggs are laid for that day. Feeding 2–3 hours after lights on can distract hens from the nests and increase floor laying.

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5. Hens may lay under bell drinkers. Nipple drinkers that are too low could be a barrier for hens trying to move to the nests. Too few nipples and low water flow could result in delays at the drinker line preventing hens from going to the nest to lay.
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6. Nests should have constant management to make them comfortable for the hens. If it is a single-hole nest, the opening must be big enough to allow the hen to enter/exit and turn around comfortably.

Nest density should be adequate. For single hole nests, it is recommended for one hole/four hens.

Nests pads and nest belts should be kept clean. Belt pads should be changed or sanitised between flocks to minimise any odour.

Nest flaps curl and get old, and expose the moving egg belt. This may scare hens; curling nest flaps should be replaced.

Nest placement may affect usage. Nests could initially be placed at floor level to encourage use, then raised up later. If the nests are tiered, perches in front of the nests could help hens reach them as well as perch while looking for a nesting site. Hens shouldn't need to fly directly to the top nest to be able to reach it.

Nests should be available before hens start to lay. If nests are opened too early, hens lose interest.

Recommended to open nests within 2 days of the first egg being laid.

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7. A tiered or slatted system should not be too high so hens have difficulty getting up onto the system, particularly as they age and become less agile. Ramps/ladders (or similar mechanism) allowing hens to step up is recommended.
-

8. It is important to train the hens to use the nests as they start to lay. Walk through the house to encourage hens to move towards the nests. Block off any other attractive nesting areas such as corners or under feeders. Operate belts in the afternoon to avoid scaring the hens in the morning. Hens will need to acclimate to the belt sound/movement.
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<https://www.humphreyfeedsandpullets.co.uk/poultry-performance-centre/2018/7/10/reduce-floor-eggs-how-to-encourage-your-chickens-to-lay-impeccably>

1. Frequently walk through the house during the first few weeks of lay and collect floor eggs as soon as they are laid.
 2. Monitor for mite infestations as these may lead to increased floor laying.
 3. Electric fencing can deter birds from specific areas such as corners.
 4. Ideal temperatures play a role, draughty nest boxes will deter hens.
 5. The rearing house needs to be set up similar to how hens will be housed during lay, and encourage movement around such as up on slats/tiers.
 6. Sunlight coming through pop-holes before house lights come on can lead to floor laying.
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<https://www.canadianpoultrymag.com/reducing-floor-eggs-17773/>

1. Birds need to be in proper body condition at the beginning of lay so they develop the natural instinct to go to the nest to lay. Correct body weight gain from 16–20 weeks is recommended.
 2. If natural light is coming into the barn as pullets are transferred to the laying facility, then there may not be adequate control of the day length.
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3. Training for jumping needs to occur during rearing, as early as 3–4 weeks of age so birds know that jumping up is ok.
4. Walk through the house when the birds first arrive at the laying facility to encourage them to jump onto the slats and become accustomed to the new system. Once light-stimulated, walking as frequently as every hour may encourage the birds to use the nest boxes.
5. Adequate nest space is important, at least 1 m²/100 birds.
6. Open up the nest flaps so the birds can see inside as they are becoming accustomed to the nests.
7. The egg belt should not be visible within the nest, so the hens are not scared by a moving belt when they are in the nest.
8. Light intensity is important. A minimum 60 lux at bird level, with even distribution across the barn to minimise shadows and dark corners.
9. Minimise the litter depth so it discourages hens from digging out nests in it.
10. Recommended to have drinker lines 60–70 cm from the nest entrance to encourage hens to come to the nest. Feed lines should be on the floor and slats so birds will use both areas. Spacing should allow birds to easily use the water and feed lines. Feeder height should allow birds to freely walk underneath.
11. Water flow rate should be sufficient so birds do not have to queue at the drinker lines, which can then block access to the nests. A minimum flow rate of approximately 60–80 ml/min is recommended.

<https://www.fwi.co.uk/livestock/poultry/how-poultry-farmer-minimised-floor-eggs-to-0-5-at-peak-lay>

1. Problems of floor laying need to be solved before hens are 40 weeks old otherwise it is too late.
2. Walk through the sheds every 30–60 mins for the first approx. 4 hours after lights come on for the first few days at the start of lay.
3. Floor eggs are collected as soon as they are found during the walks.
4. Birds are fed 15 mins after lights come on to keep them close to the nest boxes. The birds are not fed during the peak laying hours so as to not disturb the birds and detract them away from the nest boxes. They are fed during the 30 min sunrise period.
5. Rope lights are hung to minimise shadows with two sets of rope lights above the litter area. Nest areas are kept darker. Curtain flaps on the nest boxes keeps them dark and draught free.
6. Nest boxes are closed when the pullets first arrive in the laying house, they are opened up as the birds reach sexual maturity.
7. Feed and water are offered at different heights during the rearing period to get the birds accustomed to travelling up and down levels.

https://www.farminguk.com/news/dealing-with-floor-eggs-on-a-free-range-egg-unit_21534.html

1. May be related to genetics, some breeds more prone than others to laying on the floor. 'Lazy' hens not motivated to use the nest box.
2. Important for the pullets to be trained to be off the ground during the rearing period, on perches and slats, otherwise they become accustomed to resting on the ground, which may translate to laying on the ground.

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3. Pullets should be allowed to explore the nest boxes as soon as possible after arriving at the laying facility.
 4. Get the hens accustomed to the nest boxes opening before the lights come on and closing before the lights go out. If using nest box lights, they should be on before the main lights come on, but reduce the intensity in the nest boxes for the laying cycle to minimise cannibalism.
 5. If there are birds laying before the lights come on and don't make it to the nest boxes, make them go to bed later so they lay later in the day.
 6. Pick up floor eggs as soon as you see them.
 7. Nest boxes should not have draughts.
 8. Make sure feeder and drinker lines do not impede nest box access and that hens can walk along/adjacent to the nest boxes to inspect them before selecting a nesting site.
 9. Make sure the distance to walk to nest boxes is not too far.
 10. Keep light intensity higher over the litter area. Lights should not shine directly into the nest box.
 11. Electric wires around the floor litter area can deter laying on the litter.
 12. When walking through the house, pick up hens that are laying on the floor and place them in the nest boxes. This may encourage hens to lay in there.
 13. Ensure hens are roosting on the slatted area so they have easy access to nest boxes in the morning.
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<https://site.extension.uga.edu/poultrytips/2021/01/cage-free-hen-house-floor-egg-management/>

1. Lights placed under aviary units can prevent eggs laid underneath on the litter but may not prevent eggs laid out on the open litter.
 2. Control litter access when lights first come on.
 3. Even lighting across the litter floor area to prevent dim spots.
 4. Make sure litter is not too deep.
 5. Check nesting space is sufficient and comfortable.
-

Backyard poultry: <https://cluckin.net/floor-eggs-why-it-happens-and-what-to-do-about-it.html>

1. Remove eggs from the floor so hens are not attracted to lay nest to other eggs.
 2. Make sure the nest boxes do not require the hens to travel great distances to reach them.
 3. Make sure the nest boxes are not damp or draughty.
 4. Check the nesting material for parasites such as mites.
 5. Make sure hens are able to walk along the nests and look at them so they can select their ideal nesting site.
 6. Nest boxes at different heights will give hens a choice.
 7. Keep nests away from the feed and water.
 8. Keep free range hens inside until they have laid, particularly early in the laying cycle while they are establishing their routine.
-

Backyard poultry: <https://www.thespruce.com/get-hens-lay-eggs-nest-boxes-3016774>

[web page no longer available]

1. Provide sufficient nest boxes.
2. Make the nest boxes appealing, dark and quiet, clean and comfortable.
3. Collect the eggs regularly .
4. Provide enough roosting spaces so the hens are not trying to roost in the nest boxes.
5. Train the hens with dummy eggs.
6. Block off alternative floor nesting sites.
7. Keep the hens inside during the morning laying period.
8. Move hens into the nest boxes if you find them trying to lay on the ground.
9. Don't let hens sleep in the nest boxes.

Backyard poultry: <https://poultrykeeper.com/egg-problems/chickens-laying-eggs-on-the-floor/>

1. Dummy eggs.
2. Dark nests, draught-free, more attractive than other areas in the pen.
3. Start with the nest on the floor and raise up when birds are used to it.
4. Don't place nests too high or birds will roost in them.
5. Don't disturb the pre-lay behaviour.
6. Don't put nesting material on the floor.

<https://www.australianeggs.org.au/for-farmers/tools-and-training/salmonella-risk-assessment-toolkit/husbandry-and-biosecurity>

1. Encourage hens into the nest boxes before laying commences.
2. Prevent nest box access at non-laying times, e.g. at night.
3. Discourage laying in other areas e.g. with electric wires.
4. Minimal disturbance when hens are in the pre-lay and start of lay time periods.
5. Increase lighting in undesirable areas e.g. corners, floor, under cages.
6. Use nest lights to train the birds to explore the nest boxes when they are starting to lay.

<https://poultryperformanceplus.com/information-database/breeders/156-prevention-of-floor-eggs>

1. Make sure there is enough nesting space (5–6 hens per individual nest box, 35–40 birds per m in a communal nest). In hot climates, increase nesting space.
2. Do not obstruct nest entrance. If drinker lines are by the nest, drinking birds may obstruct nest entrances.
3. Do not make elevated nests too hard to jump up to. Max jumping height of 40 cm.
4. Lights should be evenly distributed to minimise dark spots.
5. Avoid thick, deep litter.
6. Avoid quiet and protected places within the shed other than the nest box.
7. Try to avoid feeding birds when they are laying so they don't need to choose between eating and laying.

Breeder guidelines and further online manuals (last accessed 29 May 2023)

<https://www.joiceandhill.co.uk/en/free-range-laying-hens/isa-brown-laying-hens/>

http://en.aviagen.com/assets/Tech_Center/Broiler_Breeder_Tech_Articles/English/AVIA-BestPractice-Floor-Eggs-2015-EN.pdf

https://canadianpoultry.ca/wp-content/uploads/2020/04/breeder_floor_eggs.pdf

https://canadianpoultry.ca/wp-content/uploads/2020/04/breeder_nest_management.pdf

<https://www.hyline.com/Upload/Resources/TU%20NEST%20ENG.pdf>

https://www.lohmann-information.com/content/l_i_43_artikel6.pdf

<https://www.cobb-vantress.com/assets/7681ca01bb/Mert-Yalcinalp-Floor-Eggs.pdf>

https://www.amt-usa.com/site_2008/files/WebsiteLinks/HowToReduceFloorEggs.pdf

6 Conclusions

The development of floor eggs is multifactorial and can be affected by the hen strain as well as individual hen preferences. Specific strains of hens may be best suited to particular housing system designs. The occurrence of the behaviour can vary across flocks in the same housing system, which means a good understanding of bird behaviour is critical for optimal management of the undesirable behaviour. However, there are common themes and strategies for management that can be considered for minimising mislaid eggs. Preventing floor laying from developing during rearing and early lay is critical, as once the behaviour is established in a flock there is very little (or nothing) that can be done to change this.

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8 Plain English Summary

Project Title:	Management tools to minimise floor eggs
Australian Eggs Limited Project No	1G014
Researchers Involved	D. L. M. Campbell
Organisations Involved	Agriculture and Food, CSIRO, Armidale, NSW, 2350
Phone	02 6776 1347
Fax	N/A
Email	dana.campbell@csiro.au
Objectives	To understand factors contributing to the development of floor laying, to identify management strategies that have been applied in the literature and in industry to reduce floor laying, and to understand new technologies that have the potential to reduce floor eggs.
Background	Floor eggs are a common problem for laying hens in loose-housed production systems both within Australia and internationally. Causes of floor eggs and methods for prevention are not always clear but floor eggs are of significant financial cost to industry through lost sales and/or increased labour. The extent of floor laying may vary among farms, production systems, and flocks. Floor laying can result in a food safety issue putting farms at risk of causing human health problems. Understanding management strategies that can prevent floor laying can help minimise this undesirable behaviour.
Research	To better understand how floor eggs may be avoided, this project compiled information on factors that can affect the propensity of hens to floor lay and management strategies that may prevent the undesirable behaviour from developing. The information review included published literature on factors affecting nest box use, genetic factors, rearing and early training factors, production cycle factors, and new technologies being developed for floor laying detection and management. The information available online in producer-aimed management documents was also compiled, and ten egg producers within Australia were interviewed to understand current practices implemented in industry.
Outcomes	The development of floor eggs is multifactorial and can be affected by the hen strain as well as individual hen preferences. Specific strains of hens may be best suited to particular housing system designs. The occurrence of the behaviour can vary across flocks in the same housing system, which means a good understanding of bird behaviour is critical for optimal management of the undesirable behaviour. However, there are common themes and strategies for management that can be considered for minimising mislaid eggs. Preventing floor laying from developing during rearing and early lay is critical, as once the behaviour is established in a flock there is very little (or nothing) that can be done to change this.

Implications	The development of floor eggs is multifactorial and can be affected by the hen strain as well as individual hen preferences. Specific strains of hens may be best suited to particular housing system designs. The occurrence of the behaviour can vary across flocks in the same housing system, which means a good understanding of bird behaviour is critical for optimal management of the undesirable behaviour. Preventing floor laying from developing during rearing and early lay is critical, as once the behaviour is established in a flock there is very little (or nothing) that can be done to change this.
Key Words	poultry; laying hen; broiler breeder; system eggs; meat chicken
Publications	Floor (mis)laid egg laying: can management investment prevent it? (submitted to Journal of Applied Poultry Research)