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Advances in keeping laying hens in various cage-free systems: part I rearing phase

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SUMMARY

Cage-free housing of pullets and laying hens is becoming more and more popular around the world. This paper reviews the literature on the most common cage-free rearing systems for pullets: floor systems with or without elevated structures, multi-tier systems, systems with access to a covered veranda and/or a free-range, and organic systems. The aim is to provide an extensive overview of various aspects of these cage-free systems, such as structure and size and functional elements for the birds. Most research on pullets in cage-free systems focuses on the prevention of health and welfare problems during the later laying period. Investigations on the actual health and welfare status during rearing are rare. There is evidence that pullets should be reared in a system as similar as possible to the later housing system for layers. Particularly for complex multi-tier systems, pullets need to develop sufficient adaptive skills. Effects of providing environmental enrichment during rearing, such as plastic objects, hay or alfalfa bales and pecking blocks, on welfare in early and later life are inconsistent across all alternative pullet housing systems. To prevent feather pecking, other factors like diet and space allowance have to be considered as well. There is a need for further research regarding free-range and organic housing systems for pullets. In addition, environmental-, economic- and food safety aspects of rearing pullets in cage-free systems should be investigated in future research.

KEYWORDS

Pullet; housing system; animal husbandry; animal welfare

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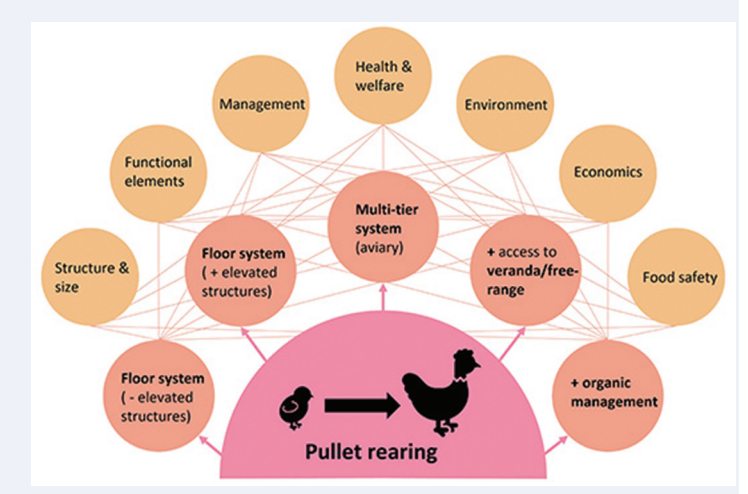

Introduction

Due to increasing societal concerns regarding animal welfare, cage-free housing systems for laying hens are becoming more and more popular around the world (Rodenburg *et al.* 2022). Conventional cages prevent hens from engaging in highly motivated behaviours, such as nesting, perching, dustbathing and foraging. Therefore, conventional cages have been banned in the EU since 2012 (EU Directive 1999/74/EU). Furnished or enriched cages provide nest boxes, perches, and a small area with substrate. However, this area and the substrate offered are often too limited for the hens to perform sufficient dustbathing and foraging behaviours. Due to increasing concerns about restrictions to hen behaviour and welfare, it is likely that furnished cages will be phased out in the EU in the near future, leaving only cage-free housing systems for keeping laying hens. Rearing systems, in which pullets are reared before transfer to the laying facility, from day-old to about 16 to 18 weeks, have received less public attention. Currently, there is also no EU legislation specifying minimum standards for keeping layer pullets, although a voluntary working group of the EU Platform on Animal Welfare has proposed guidelines (EU Platform on Animal Welfare 2021). However, a transition to cage-free housing systems for laying hens needs to be accompanied by a similar transition process concerning rearing systems. First, pullets need to become familiar with and adapt to the kind of housing system they will be kept in for the largest part of their lives. Second, if the aim is to improve the welfare of the animals, it should apply to their entire life span, not only to the stage of production. Furthermore, many welfare problems which become apparent during lay, such as feather pecking or bone damage, are influenced by the rearing environment of the pullets (Janczak and Riber 2015). The aim of this review is to provide an extensive overview of the recent scientific literature on rearing pullets in cage-free housing systems. It differs from previous focused or narrative reviews in considering all of the most common cage-free systems for pullets: floor systems with and without elevated structures, multi-tier systems, systems with access to a veranda

and/or a free-range, and organic systems. It also takes into account various aspects of these cage-free systems other than welfare, such as structure and size, and functional elements for the birds.

Methods

Literature was retrieved from 'Web of Science' using the search terms specified in Table 1. The timespan was set to '2005–2021', as this review focuses on sources that were published since the EFSA report on laying hen welfare (EFSA 2005). Only peer-reviewed original research and review articles in English were included. First, publication titles were scanned for topical relevance. Papers which met this criterion were saved for abstract reading and duplicates were removed. Finally, papers from this sample were selected for detailed analysis and inclusion in the report. Reporting was structured based on the EFSA classification of cage-free housing systems for pullets (Table 2). Mobile housing systems were not considered as no scientific literature was found on these systems. For each housing system, the articles included were structured using the following categories: 'structure and size', 'functional elements for the birds', 'management', 'health and welfare perspective', 'environmental effects', 'economic perspective', and 'food safety perspective'. If no articles were included for one of the categories for a specific housing system, this category was omitted.

The literature search resulted in 8–239 articles for the different search terms regarding pullet rearing (Table 1). After screening the titles for relevance, 0–51 articles per category were saved for abstract reading (total: 82 papers). Removal of duplicates and rejection of abstracts resulted in a total of 39 papers included in the following sections. Reasons for rejection were for instance a focus on rearing in (enriched) cages or serious flaws in the

Table 1. Literature search on housing systems for pullet rearing (Web of Science, timespan 2005–2021).

Search terms	Results Web of Science	Results after screening titles for relevance
PULLET and HOUSING	239	51
PULLET and NON-CAGE	10	6
PULLET and ALTERNATIVE	70	7
PULLET and FLOOR HOUSING	57	17
PULLET and AVIARY	38	20
PULLET and FREE RANGE	37	13
PULLET and ORGANIC	35	4
PULLET and WELFARE	159	47
PULLET and HEALTH	82	11
PULLET and ECONOMIC	42	5
PULLET and SUSTAINABILITY	9	0
PULLET and ENVIRONMENTAL	83	11
PULLET and FOOD SAFETY	8	3

Table 2. Classification of cage-free housing systems for pullets (EFSA 2005, modified).

Housing systems for pullets before egg laying	Additional features	
Floor system Floor system with single-tier or other elevated structures Multi-tier system (aviary)	Access to a covered veranda and/or a free-range	Organic management

study design, for instance comparing the daily feed intake of groups of female chickens housed in cages with groups of males and females in cage-free systems. More details on literature selection regarding housing systems for pullet rearing are presented in Supplementary file 1.

Aspects applying to all cage-free rearing systems for pullets

When keeping pullets in cage-free systems, there are several aspects that do not relate to only one of the alternative housing systems. Determining feasible stocking densities for instance will be important both in single- and multi-tier systems. The literature found on these more general topics can be found in this section.

Structure and size

In contrast to laying hens and broiler chickens, there are (currently) no legally binding regulations for maximum stocking densities for pullets in the EU. This may result in pullets being kept at very high stocking densities, which may affect their health and welfare negatively. Therefore, Krause and Schrader (2019) proposed exemplary calculations for maximum stocking densities for rearing pullets. Their calculations were based on the legal requirements for laying hens and broiler chickens and on previous planimetric studies measuring the area covered by the animals' bodies. Their suggestions aimed at being considered in future EU legislation on housing standards for pullets and being feasible for pullet rearers. If pullets should be allowed a similar relative amount of space as required for laying hens and broiler chickens, they should be provided with 40–60% space in addition to the area they cover with their bodies (Krause and Schrader 2019). At the end of the rearing period, this would ideally result in maximum stocking densities between 10 and 15 birds/m^2 for a white pullet strain, and between 9 and 13 birds/m^2 for a heavier brown pullet strain (Krause and Schrader 2019).

Functional elements for the birds

Similar to maximum stocking densities, little is known about the minimum size of structural elements for pullets. Giersberg *et al.* (2017) measured the body widths of white and brown layer pullets as a proxy for the minimum lengths of several linear features of the barn, such as perches and feeding throughs. Pullets of a white strain had a body width of approximately 13 cm at the end of rearing. At the same age, pullets of a brown strain measured 14 cm in linear body width. The authors concluded that the size of pullets must not be underestimated: at 8 weeks of age white and brown pullets reached 71% and 77%, respectively, of their adult body width. This should be considered when determining for instance the minimum perch length per pullet. When allocating resources, such as feeders, drinkers and perches in the house, it should be further considered that with increasing group size, the proportion of pullets of the whole group showing synchronised behaviour decreases, whereas the absolute number of birds at one resource increases (Keeling *et al.* 2017). Therefore, sufficient resources should be placed at different locations in the house to allow the pullets to synchronise and cluster with immediate neighbouring birds (Keeling *et al.* 2017).

In addition to basic resources, such as feed and water, environmental enrichment during rearing can help to maximise the pullets' physical, sensory and behavioural developmental potential (Campbell *et al.* 2019). This is important for birds that will be housed in complex environments, such as multi-tier or free-range systems, as adult laying hens. From their review of the literature, the authors concluded that rearing enrichment should be in line with particular features needed to adapt to the later laying hen housing system (Campbell *et al.* 2019). Pullets reared for multi-tier systems for instance would need enrichment, such as ramps, which promotes their physical ability to navigate between the tiers. However, it was also found that research on rearing enrichments on a practical level is limited, although validation data of rearing enrichments may be available for individual farms or companies (Campbell *et al.* 2019).

Management

Regarding light, it is not only important to consider light intensity and the ratio of light- and dark phases, but also the light source. In a preference test, pullets at 14 weeks of age were found to choose the type of light (incandescent or natural light) in which they had been reared (Gunnarsson *et al.* 2008). Therefore, pullets should be reared in the type of light they will be exposed to as laying hens. Pullets reared for free-range and organic systems, or indoor production systems providing daylight, should have access to natural light during rearing (Gunnarsson *et al.* 2008).

A further important management factor in pullet rearing is the implementation of vaccination programmes to prevent disease and loss due to avian respiratory viruses, such as IBV (infectious bronchitis virus), NDV (Newcastle disease virus) and ILTV (infectious laryngotracheitis virus). As vaccines are often administered serially with intervals of only several weeks, the question arises whether the birds can develop sufficient immunity or whether this is prevented by viral interference. A study by Aston *et al.* (2019) found that pullets that received multiple live attenuated vaccines against IBV, NDV and ILTV until 16 weeks of age were protected against homologues viral challenges for at least 36 weeks. Therefore, the authors concluded that pullet vaccination programmes with an interval of at least 2 weeks between vaccinations can lead to the development of protective immunity.

Van Staaveren *et al.* (2019) described the housing and management conditions on pullet farms in Canada. In Canada, there is an upcoming transition from conventional cages to furnished cages and cage-free housing systems for laying hens. Interestingly, about 42% of the surveyed farmers still reared their pullets in conventional cages. It was concluded that changes in the pullet sector regarding both changes of the housing system and financial compensation seem to take place at a slower pace than changes within the laying hen sector (Van Staaveren *et al.* 2019).

Health and welfare perspective

In general, many welfare issues in laying hens can be traced back to the rearing environment of pullets. In addition to the identification of a variety of influencing factors, the following conclusions were drawn in particular in a review by Janczak and Riber (2015): to promote high levels of welfare in laying hens, genetic lines selected

for cage-free systems should be reared; beak trimming should be limited where possible; rearing systems should provide constant access to litter substrates; perches should be present; mashed feed instead of pellets should be fed; and the rearing system should be as similar as possible to the later housing system for layers. It is also stated that for many of these factors the mechanisms underlying their effect on later welfare are not well understood, and that further research in this area is necessary (Janczak and Riber 2015).

Feather pecking is one of the most frequently observed welfare issues in hens kept in cage-free systems. It is known that rearing conditions, amongst other factors, can increase the risk of feather pecking in adult laying hens. In addition, this behaviour is sometimes observed already in the rearing phase. Dietary dilution during rearing may be one approach to reduce the risk of feather pecking by increasing feeding time and other feeding-related behaviours. Pullets fed with a 15% diluted diet showed less feather damage compared to birds fed with a 7.5% diluted diet and a standard diet (Qaisrani *et al.* 2013). Gentle and severe feather pecking behaviour, comb pecking, body weight gain and faecal moisture content decreased with increased levels of dietary dilution, whereas feeding time increased. Within the 15% dietary dilution group, faecal moisture content was lower when oat hulls instead of sunflower seed extract were used as dilution source. This may have additional positive effects on litter quality (Qaisrani *et al.* 2013).

Besides dietary dilution, there seem to be further nutritional strategies during rearing which may have the potential to reduce the risk of feather pecking during lay (Mens *et al.* 2020). Applying strategies such as influencing the serotoninergic system or the gut microbiome directly by nutrition, or increasing eating and foraging time indirectly, may alter already the pullets' physiology or train their allocation of time budgets, which may prevent feather pecking in later life (Mens *et al.* 2020). However, more research is needed, particularly on which periods during rearing would be most sensitive for nutritional intervention (Mens *et al.* 2020).

Floor system and floor system with single-tier or other elevated structures

Literature on floor systems without any tiers and on floor systems with a single tier or other elevated structures is scarce and limited to experimental setups using floor pens for pullet rearing. Therefore, scientific papers on these two systems are summarised in one section.

Functional elements for the birds

Wichman *et al.* (2007) provided pullets with perches in experimental floor pens and conducted several spatial tests to study the connection between the development of perching in layer chickens and their spatial ability. The first bird started to perch at 8 days old and all pullets ($n = 90$), except for one, were observed on the perches before 6 weeks of age. From this research, several practical conclusions could be drawn: most chickens will learn to use easily accessible perches without assistance. Furthermore, birds that had inappropriate rearing conditions can still learn to function in complex production systems, but they do not develop the same flexibility in the use of multi-tier systems as birds reared with perches (Wichman *et al.* 2007). This flexibility may be necessary to

reach resources when usual routes are blocked, for instance by dominant flock mates (Wichman *et al.* 2007).

Similar results were obtained by Ali *et al.* (2019) and MacLachlan *et al.* (2020). Birds that were reared in floor pens until 25 weeks of age showed impaired movement and vertical space use, and more falls at night in a multi-tier production system at 36 weeks of age compared to birds that were provided with perches and nest boxes at the end of rearing (17 weeks of age) (Ali *et al.* 2019c). At 36 weeks of age, birds reared with perches and nest boxes also used the top tier of the aviary more frequently in the morning and evening, and the litter area less frequently at midday compared to floor-reared birds (MacLachlan *et al.* 2020). However, at week 54, no differences were found among treatments (Ali *et al.* 2019; MacLachlan *et al.* 2020).

In addition to providing perches or other elevated structures during rearing, it may be beneficial to also offer ramps, which help the birds to easily access these elevated structures. Norman *et al.* (2018) obtained 8 week old pullets from two commercial flocks that had access to elevated structures starting at 3 weeks of age. One flock was provided with wooden ladders and grid ramps to reach the structures, whereas the other flock was not. Between 12 and 14 weeks of age, pullets from both treatments were subjected to a test situation in which they had to use a ladder or a grid to access a food reward. Significantly more pullets reared with ramps succeeded to use the test ladder and ramp compared to pullets reared without ramps. The latter group also needed more time to move upwards on the test ladder and the grid. On the first day of placement in an experimental pen, which was equipped with a single tier that could be reached by a wooden ladder and a grid ramp, the researchers observed twice the number of transitions from the floor to the tier in the pullets reared with ramps compared to the pullets reared without ramps. However, this difference was reduced on the third day. Therefore, the authors concluded that pullets seem to learn quickly to use the ramps. Within the same experimental and testing design, the pullets' preferences for either the wooden ladder or the grid ramp were also investigated (Pettersson *et al.* 2017). Pullets of 12–14 weeks of age preferred the grid ramp for moving between the floor and an elevated tier, whereas they preferred the wooden ladder for resting. Using the ladder as a perch may block it for birds moving between tiers, which would make wooden ladders less suitable in commercial systems (Pettersson *et al.* 2017). As providing ramps during rearing had no detrimental effects and it is not known how much time it would take the birds to learn in a more complex commercial facility and at an older age, it was suggested to nevertheless include ramps from the early rearing period onwards (Norman *et al.* 2018). Regarding the observations made by Ali *et al.* (2019) and MacLachlan *et al.* (2020), this seems reasonable.

Health and welfare perspective

Another study performed in floor pens under experimental conditions found a positive effect of beak trimming but not of providing environmental enrichment at a young age on plumage quality and feather pecking behaviour in adult hens (Hartcher *et al.* 2015). Birds were beak trimmed with an infra-red laser unit on the first day of life, followed by a second trimming with a hot blade at 11 weeks of age. Pullets with trimmed and with intact beaks were allocated to either pens without or with enrichment (pecking strings, whole oats in the litter and deep litter (50 mm)). At 43 weeks of age, during lay, beak

trimmed hens showed less feather pecking and a better plumage quality than hens with intact beaks, whereas there was no effect of rearing enrichment (Hartcher *et al.* 2015). However, mortality rates of pullets and adult hens were not reported. Similarly, Bari *et al.* (2021) found no effects of rearing enrichment provided in indoor floor pens on later fearfulness and use of a free-range. The enrichment materials tested

in this study were either plastic objects like pet toys, which were changed weekly, or a custom-made combination of an elevated platform and a perch (Bari *et al.* 2021). The hens' use of the free-range during the laying phase seemed to have a stronger link to several health and welfare parameters than enrichment during rearing (Bari *et al.* 2020a; Campbell, Dyall *et al.* 2020). However, another study using the same enrichment treatments found that pullets from the platform-perch group showed the highest use of a range area as adult hens (Campbell, Gerber *et al.* 2020). In addition, pullets provided with the platform-perch enrichment had a better plumage quality throughout lay and showed less behavioural modifications and physiological stress responses after an experimental change in their adult housing environment (Bari *et al.* 2020). A positive effect of the plastic object enrichment during rearing was that adult hens laid more eggs in the nest boxes than on the floor compared to the group provided with the platform-perch and the control group (Bari *et al.* 2020).

As mentioned above, rearing conditions can influence the risk of feather pecking during the later production period. Cronin *et al.* (2018) designed an experiment to test whether simulated transportation, relocation and mixing of pullets would result in plumage damage caused by feather pecking behaviour in adult birds. However, when feather pecking actually occurred at 26 weeks of age, it could be attributed more to the location of the pens in the barn than to the treatment during rearing. Pens on the south side of the barn, in which feather pecking occurred earlier and more severely, were exposed to detrimental weather conditions and wet litter to a greater extent than pens on the north side (Cronin *et al.* 2018).

Multi-tier system (aviary)

Multi-tier systems, also known as rearing aviaries are used both on commercial farms and in experimental settings.

Structure and size

Colson *et al.* (2008) demonstrated that rearing in aviaries leads to a better adaptation to layer aviaries than rearing in floor pens. Although floor pens were enriched with platforms, ramps and perches, birds from these pens showed a lower accuracy in jumps and long flights, preferred to stay on the ground and on the lowest tier of the aviary and laid more floor eggs during the production period. In contrast, pullets reared in aviaries similar to those they were housed in as adult hens used the different tiers more evenly, showed longer flights and laid less floor eggs (Colson *et al.* 2008). In a similar study, Pufall *et al.* (2021) observed a total of 15 white and brown pullet flocks reared in three different types of aviaries on commercial farms. The aviaries differed mainly in complexity: one system consisted of two tiers, one of three tiers, and one system was built of several grid platforms that could be raised as pullets grew (most complex system). White

pullet strains and pullets housed in the most complex aviary system performed the highest rate of vertical transitions between tiers and general locomotion. Accordingly, musculoskeletal development was also improved in these flocks. Therefore, white strains and pullets reared in complex systems may have an advantage when transferred to complex multi-tier systems for the production period (Pufall *et al.* 2021).

Functional elements for the birds

On commercial farms, pullets reared in aviaries are usually enclosed inside the aviary system without access to the littered area for the first weeks of their lives. Brantsæter *et al.* (2017) investigated whether providing chicks with a paper substrate during this period would reduce fearfulness at an adult age. Chicks were reared in aviaries on commercial farms with or without the paper substrate. At 30 weeks of age, birds reared on paper reacted less fearful in several behavioural tests compared to the control group. However, this was only the case for birds that did not receive environmental enrichment (various objects, as provided by the farmer) as adults (Brantsæter *et al.* 2017). For hens that did receive enrichment during lay, rearing with paper substrate or not did not make a difference in terms of fearfulness (Brantsæter *et al.* 2017).

Health and welfare perspective

Osteoporosis due to structural bone loss and resulting fractures are a serious welfare issue in laying hens, particularly during the late stages of production (after 60 weeks of age). Casey-Trott *et al.* (2017) showed that rearing pullets in multi-tier systems, with more opportunities for exercise compared to cages, resulted in a greater total and cortical bone area, greater bone breaking strength, and higher wing and breast muscle weights at 16 weeks of age. This is in line with the results obtained by Regmi *et al.* (2015), who found that rearing pullets in aviaries instead of cages leads to improved load-bearing capability and stiffness of the tibia and humerus at 16 weeks of age. Neijat *et al.* (2019) hypothesised that possibilities for exercise during rearing could also improve bone quality in older laying hens. Therefore, the researchers tested several combinations of housing systems (including cages) during the rearing and the later production phase. The most favourable bone quality characteristics at the end of lay resulted from keeping the birds in multi-tier systems, both during rearing and lay Neijat *et al.* (2019).

Liebers *et al.* (2019) investigated whether stocking density, microclimate in the barn and environmental enrichment affected the occurrence of plumage and skin damage due to injurious pecking in pullets reared in commercial aviaries up to 17 weeks of age. Pullets were housed at a stocking density of 22–23 or 18 birds/m^2 and were provided with pecking blocks and stones and alfalfa bales or no enrichment. Environmental enrichment had a positive effect on plumage and skin condition only in week 17, whereas there was no effect of stocking density. Increasing temperatures in the barn (20°C to 32°C) and increasing age (3 to 17 weeks) were associated with an increase in plumage and skin damage. It was concluded that the differences in the stocking densities tested (18 vs. 22–23 birds/m^2) might have been too small to reveal any effect on plumage and skin damage (Liebers *et al.* 2019). Schreiter *et al.* (2020a) reared pullets in commercial aviaries with and without

access to environmental enrichment (pecking stones and alfalfa bales). During the laying period, birds from these rearing conditions were assigned to four treatment groups: birds without access to enrichment materials during the whole study period, birds with access to enrichment during the whole study, birds with access to enrichment during rearing but not during lay, and birds with access to enrichment during lay but not during rearing. Effects of environmental enrichment on plumage and skin damage were inconsistent during rearing. However, during the laying period, groups that were provided with enrichment during rearing scored significantly better for plumage and skin quality than groups that never received enrichment or only during the laying period. Thus, the authors concluded that access to environmental enrichment during rearing had the potential to reduce the risk of injurious pecking during the laying period (Schreiter *et al.* 2020a). Effects of environmental enrichment on performance variables measured during the same study, such as body weight, flock uniformity, egg weights or percentage of floor eggs were inconsistent (Schreiter *et al.* 2020b).

Access to a covered veranda and/or free-range

Pullets reared for free-range productions systems are usually kept indoors during rearing. Therefore, the scientific literature on free-range systems for pullets is scarce.

Management/Health and welfare perspective

In an observational study of 33 commercial free-range laying hen flocks in the UK, having access to a range during rearing did not affect ranging behaviour during lay (Gilani *et al.* 2014). Three flocks had access to a free-range at 8 weeks of age, 13 at 16 weeks of age, and the remaining flocks had access at 35 weeks at the latest. Birds provided with a free-range during rearing did not range more frequently or further away from the barn during lay than birds that were not provided with a range as pullets. However, the authors acknowledged that all rearing flocks were relocated to laying facilities prior to production, so it is not known whether experience with the same free-range area during rearing and lay would lead to different results (Gilani *et al.* 2014). Interestingly, a correlation between range use and feather pecking behaviour during production was also not found (Gilani *et al.* 2014).

Similarly, Petek *et al.* (2015) found no differences among groups when observing the pecking behaviour of hens that had access to a free-range at 18, 20 or 22 weeks of age. However, birds that were provided with a free-range at 18 and 20 weeks had less plumage damage at 48 weeks compared to the group that had access to a range at 22 weeks. Therefore, it was concluded that early access to a free-range at the beginning of the laying phase had some positive effects on hen welfare (Petek *et al.* 2015).

Organic management

Similar to the literature on free-range rearing systems, scientific articles on rearing pullets under organic management conditions are rare. The papers presented below report findings obtained on commercial organic rearing farms.

Management

In their interviews with organic pullet rearers – a combination of commercial and backyard producers – in the UK, Sparks *et al.* (2008) found that the farmers' main motivations for adhering to organic standards were commercial interests (53.3%), followed by environmental (33.3%) and welfare considerations (33.3%). The husbandry and management conditions on the farms of the participants varied considerably: pullets were housed in units of 8 to 2500 birds and at stocking densities ranging from 1.8 to 16.0 birds/m^2. Only 15.4% of the farmers monitored the body weight of their birds, 13.3% knew the light intensity in their barn, 40% knew and controlled the temperature in their barn, and 46.2% vaccinated their flocks. Mortality during rearing was about 4–5% on most of the farms (30.8%), but a lot of farmers did not know the exact mortality figures. 25% of the farmers named smothering as the primary cause of mortality. About 40% of the organic farmers reported no constraints to rearing organic pullets; the others named factors such as capital, availability of land and inadequate margins as being the primary constraint (Sparks *et al.* 2008).

Health and welfare perspective

Organic pullet feed formulations have the potential to adversely affect bird health and welfare, because the ingredients naturally contain suboptimal levels of sulphur amino acids, such as methionine (Acamovic *et al.* 2008). In contrast to conventional feed regulations, organic regulations do not allow for adding synthetic amino acids to the feed. Therefore, Acamovic *et al.* (2008) investigated the effects of organic diets with and without (alternative) supplements on pullet health and performance. Birds were fed either a conventional control diet, a typical organic diet, the same organic diet with supplementation of methionine, or betaine, or saponin, or fructo-oligosaccharides. Until birds were given access to a free-range area, pullets fed the conventional diet and the organic diet with methionine supplementation performed better than birds from the other treatments. There were no consistent effects of the alternative supplements on bird growth, gut microbiome or the number of parasite eggs excreted. However, pullets fed the diets with low levels of amino acids seemed to have compensated for this deficiency five weeks after given outdoor access by ingesting extra nutrients from the range. Diet did not affect pecking behaviour (measured at 16 weeks of age) or plumage condition (measured at 9 and at 16 weeks of age). The authors suggested that future research should also include data from the subsequent laying period and from larger flocks, in which sufficient ranging to compensate for low levels of amino acids in the feed may not be guaranteed (Acamovic *et al.* 2008).

Feather pecking does also occur in birds kept under organic conditions. In their study of 28 commercial organic rearing flocks, Bestman *et al.* (2009) observed that 54% of these flocks showed plumage damage due to feather pecking already during rearing. The main risk factor for plumage damage during rearing was keeping pullets at higher stocking densities for the first 4 weeks of age (an average of 34 pullets/m^2 compared to an average of 21 pullets/m^2). 71% of the flocks with intact plumage during rearing did not develop feather pecking up to 30 weeks of age. Similarly, 90% of the rearing flocks with plumage damage showed also plumage damage during the laying phase. Predictors for showing

plumage damage as adult hen were: no access to litter during the first 4 weeks of age and no or not sufficient access to daylight during 7–17 weeks of age (Bestman *et al.* 2009). Similar results were obtained by Drake *et al.* (2010) who found that even slight plumage damage at 17–20 weeks of age in organic and free-range flocks was a reliable predictor for severe feather pecking behaviour later during the laying phase. Gilani *et al.* (2012) tested the effects of dark brooders on the occurrence of feather pecking on commercial organic rearing farms. Dark brooders consist of elevated heating panels with black plastic curtains on each side under which the chicks can rest in darkness, and which should mimic natural brooding. In previous small-scale experiments, dark brooders were found to reduce feather pecking (Gilani *et al.* 2012). On commercial farms, pullets reared with access to dark brooders showed less severe feather pecking behaviour during rearing and lay compared to the control flocks. Growth and mortality during rearing were not affected by the provision of dark brooders. Therefore, the authors concluded that dark brooders during rearing are a promising approach to reduce problems with feather pecking on commercial farms without affecting bird weight and mortality (Gilani *et al.* 2012).

Conclusion

The aim of this review is to provide recent detailed information on various housing and management-related aspects when rearing pullets in different cage-free systems. In general, most research on pullets in cage-free systems focuses on the prevention of health and welfare problems during the later laying period. Investigations on the actual health and welfare status during rearing are rare. There is evidence that pullets should be reared in a system as similar as possible to the later housing system for layers. Particularly for complex multi-tier systems, pullets need to develop sufficient adaptive skills and musculoskeletal characteristics. Results on the effects of providing environmental enrichment during rearing on welfare in early and later life are inconsistent across all cage-free pullet housing systems. Some authors have found positive effects of providing substrates, such as plastic objects, hay or alfalfa bales and pecking blocks, on the development of feather pecking behaviour and plumage damage, whereas others have not. Therefore, mere access to enrichment during rearing does not seem to eliminate the risk of feather pecking, but other factors such as an adequate diet and sufficient space allowances have to be considered as well. Furthermore, the effects of light and dark brooders, also in non-organically managed systems, should be reviewed in more detail. There is additional literature available on these topics, some of which have not been covered by our more general search strategy. We further conclude that there is a lack of literature on keeping pullets in systems with access to a free-range or a covered veranda or under organic management conditions. In addition, there is a research gap regarding the environmental effects, the economic perspective, and the food safety perspective of rearing pullets in cage-free systems.

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