The Influence of Laying Hen Rearing Systems and Maintenance Technologies on Egg Quality Parameters: A Review

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Abstract

This review article highlighted the effects of different rearing systems on egg quality parameters and the welfare of laying hens. Different housing systems for laying hens continue to cause controversy among consumers, researchers, environmentalists, and producers. The main concern and issue is the effect of these systems on bird health, behavior, and egg quality. In the European Union, public concern has increased about animal welfare in the poultry sector, since 2012 conventional battery cages (CC) for laying hens have been banned and replaced by other alternative housing systems: enriched cages (EC) and non-cages systems, such as aviaries (AV), and free-range system. The rearing systems and maintenance technologies of the laying hens can also influence the quality parameters of the egg. Conventional rearing systems can involve overcrowding of hens, poor hygiene conditions, or lack of access to space and natural light, which can lead to stress and disease in the birds and, by implication, reduced egg quality. The use of modern technologies in the breeding of laying hens can contribute to the improvement of egg quality parameters and the well-being of laying hens. These technologies include automated systems for feeding and watering, temperature and humidity control in rearing houses, artificial lighting, and the use of food supplements to ensure adequate nutrient intake.

Keywords: egg quality, hen welfare, laying hens, physical characteristics, production system.

1. Introduction

In all the European Union, conventional battery cages (CC) for laying hens have been banned since 2012 and replaced by alternative housing systems including enriched cages (EC) and non-cages systems such as aviaries (AV), deep litter, and free-range systems [1,2].

Various types of housing systems for laying hens are still the subject of debate in the academic community, among producers, ecologists, and consumers. The major impact is that these systems have a negative effect on the health and natural freedom of the hens. These systems have a direct and indirect impact not only on the behaviour, productivity, and health of the hens but also on the quality of the eggs produced [3,4].

Previous research has focused on evaluating the impact of different housing systems on bird health and welfare, as well as egg quality. Currently, egg production in the European Union is predominantly based on the use of the enriched cage system [5].

The housing system in which laying hens are kept can significantly impact egg production performance [6]. Based on the relevant scientific literature, this scientific review analyses the relationship between housing systems and egg performance, including factors such as egg quality and nutritional content.

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2. Housing systems of laying hens

An ideal laying hen housing system should prioritize the natural behaviours of birds, reduce the risk of disease and injury, maximize egg production and quality, and enhance food safety [7].

Intensive production in battery cages has brought significant benefits to table egg production, improving production levels, economic efficiency, and hygiene-health safety. However, in the context of legislative regulations emphasizing animal welfare and banning cage-rearing systems, there is an increase in interest in alternative production systems [8]. Alternative growing methods include barn and outdoor growing. Barn-raised chickens are raised without cages but are kept entirely indoors, while free-range chickens are always outside [6]. Alternative production systems, such as aviaries and enriched cages, are becoming increasingly popular in the poultry industry due to their ability to enhance chicken welfare [9]. However, traditional battery cages, while efficient for egg production, have been shown to have negative impacts on the well-being of the birds.

Ecological aspects, the perception of superior quality, and the biological safety of products from less intensive systems are becoming increasingly important in global table egg production [8].

2.1. Conventional cage (CC)

One of the most well-known housing systems for laying hens is the conventional cage system (CC), which has been widely used in the past. This system consists of raising laying hens in small cages, providing egg collection efficiency and limited space for movement but with negative effects on egg quality and hen health, research by Rodenburg et al, 2010 revealed high levels of stress [10]. Conventional battery farming is a method of raising laying hens in a controlled environment, such as closed or "blind" houses. This technology was developed to meet the increased demand for eggs for human consumption and opened the way to intensive industrial egg production systems. One of the problematic aspects associated with conventional cages is the limited space available for each individual hen. Specialist studies have shown that hens placed in conventional cages, due to the lack of the possibility to manifest their natural behaviours such as nesting, perching and dust bathing [11], are exposed to an increased level of stress. This phenomenon can lead to negative consequences on the well-being of hens, including manifestations of aggression, feather pecking and decreased egg production. Furnished cages must provide at least 750 cm^2 per hen, of which 600 cm^2 must be 45 cm high, a nest, a complete scratching and pecking area, a 15 cm nest per hen, a feed trough of 12 cm per hen and a nail shortener [6].

While conventional wire cage systems are cost-effective and can help prevent diseases and pecking, they limit the ability of birds to engage in natural behaviours such as nesting, roosting, walking, foraging, and dust bathing [7]. Hens housed in enriched cages were found to lay more eggs than those in conventional cages [12]. In the study of Englmaierová M. et al, the highest hen-day egg production was recorded from the enriched (92.2%) and conventional (91.3%) cages, compared with the litter housings (79.8%) and aviaries (71.8%) [12].

2.2. Enriched cage (EC)

This system has been shown to be the most efficient form of egg production. According to the study by Biesiada-Drzazga and Janocha, the cage system has many advantages over the stable housing system, as it allows a higher density of birds per unit area [5]. At the same time, the proper hygiene of the cage system, through proper excrement management, regular cleaning of feeding equipment and egg transport systems and drinking water, is essential for obtaining high-quality eggs. Moreover, Hartcher, K. and Jones, B., found that hens in enriched cages displayed reduced levels of stress-related behaviours compared to those in conventional cages [13]. A particular advantage is that the cage system provides protection for the birds against predators and allows control of the rearing environment [5].

Enriched cage systems are specifically designed to promote natural behaviours in chickens, such as wing-flapping, perching, nesting, dust bathing, walking, and exercise. These systems provide more space for the birds to move around and exhibit these behaviours, leading to improved leg health and decreased fearfulness [9]. Additionally, the increased space and freedom of movement in enriched cages and aviaries result in higher levels of physical activity and fewer fractures or other

problems, which ultimately improves product quality. Rodenburg et al. observed keel bone fractures in furnished cages, houses and aviary systems and found that there was a difference between these rearing systems where they recorded fewer hens with keel fractures in furnished cages (62%) compared to cage-free systems (82% and 97% respectively) [10].

2.3. Aviary system (AV)

Enriched cages and aviaries are alternative housing systems designed to improve the welfare of animals by providing them with more space and resources to allow them to exhibit their natural behaviours such as nesting, perching, or scratching [2]. The aviary is a technological solution that combines the advantages of growing on permanent bedding with those of the rearing system in batteries (the surface available to the hens is multiplied according to the number of levels of the aviary, the hen having the possibility of to walk freely and upright). Although avian systems offer more opportunities to perform natural behaviours compared to cage systems, feather pecking continues to be a major welfare problem that is difficult to detect [14,15].

2.4. Free range and organic

In free-range production systems, including organic ones, the quality of the pasture, the season and the length of time the hens spend outside are particularly relevant factors for egg quality. However, these factors are difficult to control [6]. On the other hand, the potential health risks associated with large group sizes and exposure to litter cannot be ignored, but they must be balanced with the benefits of access to natural behaviours provided by the free-range system [7]. While outdoor access may increase exposure to climate variations, diseases, and predators, it also allows hens to engage in natural behaviours that contribute to their overall well-being. Furthermore, Rodenburg et al. observed that hens in free-range environments had lower mortality rates and exhibited more natural behaviours than those kept in battery cages [10].

Petek et al. showed that the cracked egg rate in free-range systems was higher compared to cage systems [16]. Also, in the study by Petek M. et al. showed that egg production and percentage of cracked eggs were better in cage system (95.50% and 1.50% respectively), daily feed intake (94.81 g) and feed consumption per egg produced (109.66 g feed/egg) were considerably lower in open-air layers. The percentage of cracked eggs decreased with age in the free-range system from 3.10% at weeks 24-28 and 0.90 at weeks 32-36 [16]. The difference in feed consumption between the two systems could be attributed to the environmental conditions in outdoor settings. It is possible that the lower feed consumption in free-range hens is due to their ability to meet their nutritional needs by foraging on vegetation, worms, and insects while outdoors.

In the research of Lordelo et al., eggs from hens raised in an ecological production system, both native and organic, had a higher white content and lower percentages of yolk, estimated for the whole egg, compared with eggs from other rearing systems [6]. This percentage variation can also be explained by the age and breed of hens involved in egg production, not just the rearing system.

Organic eggs can be defined as the product of a rearing system that absolutely avoids conventionally grown feed, including GMO's (genetically modified organisms or crops), animal byproducts, and synthetic additives [17]. Only organically grown grains are used, oil seeds and roughage, and the birds are given free access to outdoor areas, which lower certain stresses [18]. However, the costs of producing eggs from certified methods are significantly higher compared to conventional methods. This is due to factors such as longer growing times, higher feed consumption, reduced productivity, and fertility [4].

3. Egg quality

Hen eggs are very nutritious, tasty and cheap. Consumers are increasingly interested in the welfare of chickens and their eggs. To meet consumer demand, producers have begun to market eggs laid by hens raised in alternative production systems and with improved nutritional content due to the feed used [6].

3.1. The factors that influence egg quality

Egg production and quality are critical to the success of an egg farm and are influenced by a number of genetic and environmental factors (Figure 1). The housing system of the birds and the diet they receive are key factors that can improve the health and quality of the eggs produced [9]. Yilmaz Dikmen et al., found a

significant interaction between age and housing system in yolk weight [19]. Kraus et al. al., showed that the egg weight was significantly ($p \leq 0.001$) influenced by age, housing system and their interaction.3. factors that can affect egg production and quality [20].

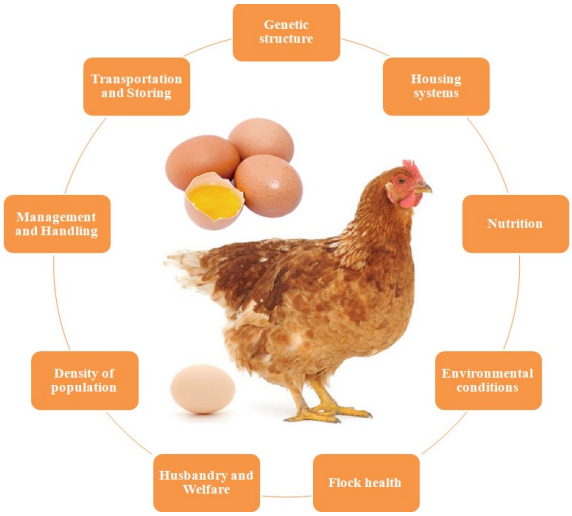

Figure 1. Schematic overview of the main factors that can affect egg production and quality [9].

3.2. Egg production

While the productivity parameters of conventional cages (CC) and enriched cages (CE) were found to be similar in the study conducted by Philippe et al., it was observed that aviary systems (AV) exhibited a decrease in performance [2]. This included a lower laying rate, decreased egg weight and quality characteristics, as well as a higher percentage of eggs being laid outside the nest. Similarly, other studies [16] showed a lower production percentage at AV (88.60%) and a decrease in egg weight (60.30%). These factors ultimately led to reduced profitability in AV systems. In the study of Philippe et al., about 70% of the eggs were laid in nests with EC, while almost all eggs were laid directly on the litter in the case of the AV system. As the AV system presents a low level of egg hygiene, this led to a low overall proportion of clean eggs (13.9%) compared to cage systems (about 77%). Englmaierov´a et al. observed that traditional cages had the highest egg production and the lowest daily feed consumption and feed conversion ratio when compared to litter and aviaries.

3.3. Egg composition

The egg is nature's most complete food, with high-quality proteins and a 2 : 1 unsaturated fat to saturated fat ratio [9]. It is an excellent source of iron, phosphorus, other minerals, and vitamins less vitamin C [21]. It is well known that the protein content of the egg is strongly influenced by the diet of the hen and less by the rearing system [6]. In contrast to Free-range and organic eggs, a higher protein content was found in the albumen of eggs from caged hens.

Several consumers associate egg yolk colour with hen health and egg quality, eggs with a yellow to orange yolk are preferred [22]. Carotenoids are naturally present in egg yolk in varying amounts depending on the hen's diet. The inclusion of parsley and inulin in the ration has effects on the enrichment of antioxidant nutrients in the egg yolk and the susceptibility of the yolk to lipid peroxidation during storage [23]. Lighter yolk colour in eggs from hens raised in organic systems was observed in the study of Lordelo et al. [6]. Results of other research showed a darker colour of the yolk in eggs from hens raised in cages, compared to those raised in alternative production systems [17,24]. On the other hand, other studies have recorded darker yolk colours in eggs from hens reared in outdoor rearing systems, this is due to access to food rich in carotenoid pigments, such as grass and herbs [25]. Similarly, studies by Dong et al. (2017) discovered that eggs from free-range hens had a more intense yolk colour than those from conventional cages [26]. However, yolk quality is not constant because carotenoid-rich feed is not available throughout the year or not all hens have access to outside feed due to environmental conditions [27].

3.4. Egg wight

A high egg weight is the most significant physical characteristic of hen eggs observed by consumers. This is also an essential characteristic of egg quality and is included in the marketing rules that classify eggs into four weight categories according to Commission Regulation (EC) no. 589/2008 [4]. Lewko and Gornowicz, show that caged hens were they had the heaviest eggs (61.06 g) and the highest percentage of albumen and yolk in the egg. Eggs laid by caged hens were characterized by yolks with the highest weight (18.20 g). Studies such as Van Den Brand et al., reported that free-range layers produced heavier eggs

(56.41 g) with a higher shape index (75.44%) and a higher percentage of albumen (59.05%) and shell (12 .64%) in egg weight [28]. The study of Lewko and Gornowicz, showed similar results, the highest egg shape index (79.29%) was characteristic of eggs from free-range, followed by eggs from the litter system (79.00%), with statistically significant differences about the cage system [4].

In the study Lordelo et al., shell percentage did not differ between production systems, but differences in egg weight were found, with caged hens producing heavier eggs [6]. However, shell pre-cracks were more prevalent in eggs laid by caged hens. Furthermore, similar values were shown in the study of Philippe et al., the egg weight presented no statistical difference between CC and EC (around 59.5 g) but was lower in AV at 58.6 g, but the difference was significant only at the beginning of the experiment [2,29]. The same findings were observed for egg length and width concerning the effect of the housing system and time [2,30].

4. Conclusions

Alternative production systems provide a more humane and welfare-friendly option for laying hens compared to traditional battery cages by improving comfort levels and promoting natural behaviours. The eggshell quality and egg weight of hens raised in both conventional cages and enriched cages were found to be superior, compared to other systems. The housing system and nutritional intake of hens play an important role in determining the production and quality of eggs.

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