



## Environmental Enrichments in Laying Hen Production Systems with Emphasis on Welfare and Egg Quality

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### ABSTRACT

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To improve hen welfare, several studies have investigated various environmental enrichments that suit different laying hen production systems. The positive results of these studies can enable such environmental enrichments to be utilized in commercial laying hen production. This paper reviewed the effects of environmental enrichments in different laying hen production systems on hen welfare and egg quality. The successfully proven environmental enrichments in free-range production system include forage, shelterbelt, and artificial shade in outdoor area and novel objects and H-shaped perching structures in indoor. These are associated with increased range use that positively affects hen welfare. In aviary system, perches, and litter materials (e.g., straw, sand) as environmental enrichments are linked to improved behavioral expression, reduced stress, and enhanced immune system. Under the litter system, environmental enrichment with substrates (e.g., pecking stones, alfalfa blocks, silage, straw, barley) has been found to increase the foraging behavior of laying hens. This reduces severe feather pecking thus, improving the plumage condition of hens. Although the effects of environmental enrichments on hen welfare have been assessed and scientifically proven in the reviewed studies, significant progress of their impact on egg quality traits has not been reported. The studies have shown that environmental enrichments have no significant effect on egg quality traits. Also, appropriate pasture or plant species as environmental enrichments in free-range production system in relation to hen welfare and egg quality have not been identified. Therefore, it is important to continue studies on environmental enrichments while emphasizing their influence on egg quality since it is a major performance trait in the egg industry. In addition, there is a need for studies to identify ideal pasture or plant species for free-range production system that positively affects hen welfare and egg quality.

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### Introduction

The production of laying hens in conventional cages is the most common system worldwide (Mench and Rodenburg, 2018). However, conventional cages have been banned in various countries including Switzerland, Austria, and the European Union since 1992, 2009, and 2012, respectively (Appleby, 2003a and 2003b). The legal ban on battery cage rearing of hens led to the development and implementation of welfare standards for laying hen production (Bessei, 2018). In some countries, cage systems laying hen production will be phased out over time (e.g., from 2025 in Germany, from 2027 in the Czech Republic) (Sokołowicz et al., 2020). Thus, producers in such countries are mandated to rear hens in alternative production systems that improve hen welfare (Stadig et al., 2016; Campbell et al., 2019). However, it is established that the requirements needed to enhance hen welfare

increases the cost of production. Thus, in developed countries, harmony is reached between the implementation of welfare standards and the extra price for eggs produced in a welfare-friendly system (Bessei, 2018). Enhancement of hen welfare is a vital indicator of hen's livability, health, and productivity (Tainika and Şekeroğlu, 2020). However, hen welfare is affected by several factors such as environmental enrichments (Bari et al., 2020c; Campbell et al., 2020b; Iqbal et al., 2020; Schreiter et al., 2020c); stocking density (Campbell et al., 2017; Singh et al., 2017), production system (Campbell et al., 2020a; Cronin et al., 2020; Petek and Çavuşoğlu, 2020), genetic strain (Morrissey et al., 2016; Giersberg et al., 2017; Giersberg et al., 2020; Schreiter et al., 2020c), husbandry practices (Morrissey et al., 2016), the interaction between humans and animals, etc. (Hartcher and Jones, 2017; Rufener and

Makagon, 2020). Campbell et al. (2019) reported that provision of environmental enrichment improves the hen's development ability to adapt to alternative production systems. Environmental enrichments are defined as any modification with practical and economic benefit (e.g., reduced intake of commercial feeds, hygienically safe) within the hen's environment, and is aimed to have a positive influence on the hen including physiological development (e.g., enhanced musculoskeletal strength, brain development), increasing expression of natural behaviors (e.g., dust bathing, foraging, perching, nesting), the potential to decrease the prevalence of abnormal and damaging behavior (e.g., reduced feather pecking and cannibalism), reducing stress, enhancing the hen's health condition (e.g., decreased osteoporosis, reduced keel bone damage, improved plumage condition), and boosting the utilization of environmental resources offered to the animal (Newberry, 1995; Weeks and Nicol, 2006; Riber et al., 2018; Campbell et al., 2019). Some studies have reported that there is a significant effect of environmental enrichments on internal and external egg quality characteristics (Bari et al., 2020a and 2020b). Examples of environmental enrichments include perches, edible particles, furnishings, and producing hens in alternative systems that are more complex. It is emphasized that environmental enrichments may influence the modern genotypes in different ways due to genetic selection which continuously modifies their behavioral traits (Campbell et al., 2019). Environmental enrichments within the literature are vital for future research to determine commercial enrichment architectures to enhance hen welfare. Therefore, this review highlights on effects of some environmental enrichments in laying hen production systems on hen welfare and egg quality.

### Hen welfare

In the 1960s, a report submitted to the United Kingdom government laid a foundation for the current policies on animal welfare (Scanes, 2016). The report documented the known five animal freedoms stated below:

- Freedom from hunger, malnutrition, and thirst (all time accessibility to quality feeds and water).
- Freedom from discomfort (e.g., thermal comfort, provision of appropriate beddings).
- Freedom from disease or injury or pain (e.g., early disease diagnosis, early treatment).
- Freedom from fear or distress or mental discomfort (ensuring positive emotional state).
- Freedom to express natural behaviors (e.g., provision of enrichments within the animal's environment).

The concept of welfare and stress are highly linked and may be regarded as opposites since welfare is unattainable under stress and vice versa. Thus, welfare can be defined as stress-free or reduced level of stress (Veissier and Boissy, 2007; Scanes, 2016). Furthermore, it is known that the concept of animal welfare is multidimensional and assessed under four principles including good nutrition, good housing, good health, and behavioral expression. Within these principles, the procedures for protecting the hens from suffering, hen management, and the hen housing environment are assessed for welfare standards (Welfare

Quality, 2009). Various laying hen welfare parameters have been studied and some examples include the following:

- Plumage damage and feather score (Giersberg et al., 2017; Pichová and Bilčík, 2017; Campe et al., 2018; Decina et al., 2019).
- Stress (Carvalho et al., 2018; Tilbrook and Fisher, 2020; Du et al., 2020).
- Keel bone disorder (Rufener et al., 2019; Toscano et al., 2020; Thøfner et al., 2020; Kittelsen et al., 2020).
- Footpad health (Wang et al., 1998; Heerkens et al., 2016a and 2016b).
- Mortality rate (Iqbal et al., 2020; Milisits et al., 2021; Saraiva et al., 2021)

Some methods that have been used to assess hen welfare parameters include:

- Radio-frequency identification (RFID) systems for determining ranging behavior (Larsen et al., 2017; Campbell et al., 2019; Bari et al., 2020a; Taylor et al., 2020).
- 1, 2, or 3 scoring scale for keel bone damage after palpation (1. no damage, 2. mild, and 3. moderate damage) (Bari et al., 2020c).
- Validated radioimmunoassay for albumen corticosterone levels as an indicator of stress (Bari et al., 2020c; Caulfield and Padula, 2020).
- Counting of fresh or healing comb wounds in addition to observing under light for variation in comb color for comb wounds (Welfare Quality, 2009; Petek and Çavuşoğlu, 2020).
- 1-4 scoring scale for footpad lesions (1. swollen, infected bumblefoot, 4. normal footpad with the absence of lesions or dermatitis) (Welfare Quality, 2009; Alberghina et al., 2020; Van den Oever et al., 2020)
- 1-4 scoring scale for feather loss or plumage damage at different body regions (head, neck, breast, back, wings, and tail) of the hen (1- no feathers, 2- half feather 2/3 loss, 3- 1/3 feather loss, and 4- full feather coverage) (Tauson et al., 2005; Bari et al., 2020c; Onbaşlar et al., 2020).

However, feather score for the neck region is conducted separately because most of the damages on the neck are not closely associated with detrimental effects of pecking behavior (Tauson et al., 2005; Bari et al., 2020c). Several studies have reported that environmental enrichments in the various laying hen production systems can modify hen welfare (Matur et al., 2016; de Koning et al., 2019a; Bari et al., 2020c). Hofmann et al. (2020) stated that the housing environment potentially impacts the immune system of hens but recommended that the choice of an environmental enrichment in the production system should be determined according to the particular need of hens. Sharma et al. (2021) suggested that housing environment has a profound influence on bone strength though it varies between strains. Li et al. (2021) emphasized that environmental enrichments in laying hen housing system potentially decrease the damages associated with stress during their transportation (e.g., from growing to egg production pens, to slaughter plants). Furthermore, environmental enrichments were found to have an extreme effect on

chicken's inherent ability to adapt to aversive stimulus (Ross et al., 2020). Housing systems with enrichments or that allow hens access to outdoor satisfy the consumer's preference for welfare-friendly egg production. This is because such approaches have an increased potential to enable hen's expression of several behaviors that enhances its welfare (Bennett et al. 2016; Chiello et al., 2016; Schreiter et al., 2019; van Staaveren et al., 2021).

#### ***Effects of Environmental Enrichments On Welfare of Laying Hens in Free-Range System***

Nagle and Glatz (2012) determined that enriching free-range area with waterproof shade cloth, forage (vetch and wheat pastures), and shelterbelts has a significant benefit of attracting hens into the range. However, the level of hen's attraction was highest, moderate, and lowest into the range with forage, shelterbelt, and artificial shade enrichments, respectively. It was emphasized that the type of outdoor enrichment influences the chicken's motivation to access outdoor areas, and farmers should ensure provision of enrichments to attract hens into the outdoor area for appropriate range use. Furthermore, it was maintained that within a large population feather pecking and cannibalism are prevalent even with environmental enrichments.

Indoor environmental enrichment with novel objects (e.g., balls, brooms, ropes, containers, bottles, etc.) that were changed weekly (novelty) and H-shaped perching structures (structural) during the rearing period until 16 weeks was reported to have several effects on welfare and behavior of free-range hens. These included:

- Decreased ranging time and toenail length (mm), and reduced feather loss or damage, and comb wounds (Bari et al., 2020c).
- Decreased floor eggs for novelty hens (Bari et al., 2020b).
- Increased ranging time and albumen corticosterone for the structural group (Campbell et al., 2020).

Furthermore, Bari et al. (2020c) indicated that the age of hen and environmental enrichment treatments had significant interaction effects on hen welfare parameters (e.g., percentage of wounded combs, feather condition, the length of the toenail, and albumen corticosterone levels). However, differences in some welfare parameters were observed between the novelty object and H-shaped perching structural groups. For example, after imposing a stressor in the range area, egg albumen corticosterone concentration decreased in the H-shaped perching structural group and increased in the novelty group post-stress. On the other hand, no significant difference for ranging time was observed between the two environmental enrichment groups. Campbell et al. (2020b) observed that different environmental enrichments (novelty object and H-shaped perching) affect the ranging behavior of hens, but range use is age-dependent (increases with advancing age). Bari et al. (2020b) identified a significant interaction between environmental enrichment (novelty object and H-shaped perching) and laying nest utilization for the hens from 18 to 64 weeks of age. Since the highest number of eggs laid in nest boxes was found in novelty compared with structural and non-enriched groups, it was suggested that environmental enrichment with novel objects may boost

the hen's exploratory potential to new environments. This enables the easy establishment of nest box laying patterns which is an indicator of enhanced hen welfare.

Larsen and Rault (2021) observed that commonly expressed behaviors by laying hens under environmental enrichment with materials produced from hardwood, pine, and dark green shade sailcloth included pecking, scratching, and vigilance. It was argued that the complexity of environmental enrichment in terms of material, structural design, and placement (height and direction) into the laying hen house influences free-range hens to express many behaviors on the farm. The effect of designing a material package for decreasing conspecific pecking behavior and increasing the percentage of range hens in the United Kingdom free-range farms was investigated by Pettersson et al. (2017). It was determined that environmental enrichment (pecking pens, coarse materials, specially designed shelters) decreased gentle and severe feather pecking behavior, and enhanced range use in layer hens (increased number of hens more than 6 meters from the pen).

In another study, de Koning et al. (2019b) observed that range use was not affected by environmental enrichment with the saltbush plant (*Atriplex nummularia*). It was postulated that the effect was due to low height levels of saltbush which could not offer shelter supplementation. However, it was concluded that inclusion of saltbush plants free-range ensures shade and shelter in low rainfall areas thus, protecting hens from harsh weather conditions.

#### ***Effects of Environmental Enrichment On Welfare of Laying Hens in Aviary System***

Nørgaard-Nielsen et al. (1993) argued that aviary systems should allow hens exposure to sand and peat for dustbathing behavior while in the rearing stage and environmental enrichment with harvested straw during the laying production period since they both decrease the frequencies for feather pecking thus decreasing plumage damage. When Regmi et al. (2018) investigated the welfare and production issues of different litter substrates (Astroturf, wood shavings, or straw and bare concrete floor as control) in a multi-tier aviary system, it was identified that in the first cycle crop feather loss was higher in Astroturf than straw treatment at mid-lay. However, in all the litter substrates, keel deformations increased with advancing age.

Brantsaeter et al. (2016) found that rearing laying hens in a complex aviary environment (cages fitted in three tires with cage dimensions of 120 cm × 80 cm × 60 cm) had effects that included lowered levels of fearfulness in hens both at 19 weeks and at 23 weeks of age, increased active behavioral response (fly up stimulated by exposure to a novel object at 19 weeks), and increased perching at 19 weeks as revealed by spatial distribution compared with barren cage environment. However, there was no significant difference between the two groups for stress levels as indicated by incidence of defecation or level of fecal corticosterone concentration at both 19 and 23 weeks of age. Their findings supported the hypothesis that housing laying hens in a multiplex environment impacts their behavior response. The positive effect on behavior response would be linked to the complexity of the rearing environment having the potential to influence brain

morphology and neurochemistry, and stimulate brain development in birds (Tahamtani et al., 2016). However, in early life, rearing laying hens in barren environment is reported to harm their spatial cognition (Tahamtani et al., 2015). In another study, Campderrich et al. (2019) explored the hypothesis that housing laying hens in a complex environment that is enriched with firm cube-like material, disc-like perches, and hiding regions within the pullet stage ensures their adaptability to traumatic conditions and protect the animals against subsequent traumatic periods. It was observed that the response of hens under cold stress and reared in a complex environment is proportional to the response under a stress-free environment. Furthermore, it was established that rearing hens in a complex environment significantly improved pro-inflammatory response, enhanced response while adapting to new challenges of intermittent stressful challenges protocol, and lowered heterophil/lymphocyte ratio after intermittent stressful challenges protocol. It was indicated that commercial rearing of laying hens in a complex environment decreases the negative effects of cold stress, and in terms of adaptive plasticity theory, it was suggested that there are long-lasting effects on the expression of the hen's observable features due to early experience.

Sirovnik et al. (2018) observed that feeding of hens from perches has considerable benefits such as lowered mortality, and aggression all of which are good indicators of enhanced welfare in aviary system compared with feeding on platforms. Furthermore, effect of perch installation in three different aspects including direction (upward vs. downward), angle (flat vs. steep), and distance (50 cm vs. 100 cm) on laying hens after 16 weeks of age was evaluated by Rufener et al. (2020). It was revealed that hens had difficulties in navigating distances of 100 cm and steeper angles in addition to a need for a higher force at the keel during downward movements however, the effects vary between genotypes. In addition, it was concluded that appropriate installation of perches in terms of direction, angle, and distance enhances the environment in the aviary system that reduces keel bone damage in laying hens. Furthermore, several studies have reported that environmental enrichment with perches in the aviary production system improves hen welfare and behavior (Sirovnik et al., 2018; MacLachlan et al., 2020). However, perches are associated with keel bone damage in the aviary system (Rentsch et al., 2019; Baker et al., 2020). Sirovnik et al. (2018) determined that the negative effects of perches are linked to position, material, and shape of perches. Thus, during the installation of perches in the aviary system, their positioning is very vital to laying hens. For example, top-tier perches are used for roosting (Brendler et al., 2014; Campbell et al., 2016b), and perches positioned between or across the aviary tiers facilitates easy movement of hens between the tiers (Campbell et al., 2016a). It was strongly emphasized that selection of elevated structures such as perches should be done under consideration of the breed although all genotypes prefer elevated structures for roosting (Malchow et al., 2019). For example, in a comparison study between conventional layers and dual-purpose hybrids, it was found that there was a significant difference for linear space requirement and perch use between the two genotypes (clear preference for roosting on the highest perches was shown in dual-purpose hybrids)

(Giersberg et al., 2019). In a study, Stratmann et al. (2015) concluded that environmental enrichment of aviary system with design ramps and platforms has great potential to decrease keel bone damage of laying hens. Hu et al. (2019) examined the effect of water-chilled perches on hen production and physiological responses to induced molt during elevated temperatures in White leghorn. It was observed that hens housed under water-chilled perches had higher breast and lower vent feather scores besides the enhanced potential to cope with induced molting and aversive stimulus compared with hens reared under air perches and no perches.

#### ***Effects of Environmental Enrichments On Welfare of Laying Hens in Litter System***

Several studies have established that provision of substrates or edible objects in litter system for laying hen production is the most effective approach to reduce feather pecking. For example, Blokhuis and Van der Haar (1992) identified that environmental enrichment of litter system with additional straw and cereals during the rearing of hens reduced feather damage within the laying period. This was associated with the potential of such enrichment materials in restricting hens from redirecting ground pecks towards feathers of conspecifics. Steinfeldt et al. (2007) examined the effect of using maize silage, barley and pea silage, and carrots as foraging materials for egg-laying hens on feather pecking. It was found that the three substitutes reduced damaging pecking, decreased severe feather pecking behavior, and enhanced plumage condition. It was concluded that allowing hens access to various types of foraging sources improves hen welfare. Cronin et al. (2018) investigated the effects of stimulating foraging behavior from week 16 on the occurrence of severe feather pecking in laying hens reared for the free-range egg system. Daily provision of forage (200 g of chopped barley straw) in dispensers allowed pecking, grasping, pulling, and removal of the straw. It was reported that the enrichment treatments had a better plumage condition compared with the non-enriched group.

In two separate trials, McAdie et al. (2005) studied the effects of providing string devices (white polypropylene baling twine) on feather pecking in a trial with litter system for hen production and on feather condition under commercial conditions. In the first trial, it was observed that installation of string devices from 1 day of age or offering string devices in the laying hen pens for 4 hours per day practically eradicated feather pecking. Furthermore, in the second trial, hens that were reared for 16 weeks then transferred to battery cages with installed string devices had improved plumage condition at 35 weeks of age compared with hens reared in battery cages without devices. It was confirmed that installation of a device in battery cages acts as a substitute for pecking. Hartcher et al. (2015) assessed the effects of environmental enrichments (pecking strings, whole oats in the litter, and greater litter depth) in litter system from 12 days of age during rearing on behavior and feather condition of hens. It was stated that environmental enrichments did not affect the plumage condition of hens. In another study, Zepp et al. (2018) evaluated the effect of stocking density and inclusion of enrichment materials (pecking stone, pecking block, and alfalfa bale) on development of feather pecking

in hen chicks under commercial rearing conditions. It was confirmed that low stocking density and environmental enrichments reduced the occurrence of feather pecking and aggressive pecking in laying hens. This low deteriorating effect on plumage condition and the plumage condition assessment is a reasonable measure of feather pecking. Similarly, Liebers et al. (2019) stated that environmental enrichments (pecking stones, pecking blocks, and lucerne bales) during the rearing of laying hens on litter from 5 weeks of age significantly improved plumage condition at 17 weeks of age. Schreiter et al. (2020c) investigated the effect of additional environmental enrichment materials (pecking stones and alfalfa bales) on prevalence of plumage damage, skin injuries, and toe injuries while emphasizing the possible differences between laying hen genotypes (Lohmann Brown classic, Bovans Brown, Lohmann Selected Leghorn classic and Dekalb White). It was reported that environmental enrichments improved the plumage condition in all the genotypes excluding Bovans Brown groups, decreased toe injuries for the genotypes excluding Lohmann Selected Leghorn classic groups, and reduced skin injuries in Lohmann Selected Leghorn classic groups compared with non-enriched treatment. Furthermore, it was stated that variation in hen welfare parameters between genotypes is a result of genotype-environment interaction. In addition, it was argued that it is useful to consider the laying hen genotypes before selecting environmental enrichment materials. Similarly, the effect of environmental enrichment materials (pecking stones and hard-pressed alfalfa bales) in litter housing system and laying hen genotypes (Lohmann Brown classic and Lohmann Selected Leghorn classic) on integument conditions was assessed by Schreiter et al. (2020a). It was observed that at 40 weeks of age, hens that were housed in enriched pens during the rearing period only had: reduced feather damage, and lowered skin injuries within Lohmann Selected Leghorn hens. Furthermore, environmental enrichment during the laying period reduced the beak tip protrusion of hens at 48 weeks of age. However, environmental enrichment during the entire study highly enhanced plumage condition, reduced skin injuries, and beak tip protrusion of hens. This was associated with enrichment materials having the potential to promote foraging behavior and abrasion of the beak-tip.

### **Egg Quality Characteristics**

Globally, external and internal egg quality characteristics are fundamental to the egg industry (Bain et al., 2016). The external quality is composed of egg size or weight, egg specific gravity, shell color, shell breaking strength, shell deformation (destructive or non-destructive), shell weight, percentage shell, shell thickness, and shell ultrastructure (Bain et al., 2016, Rath et al., 2015). Traits of internal egg quality include yolk color score, perivitelline membrane integrity, albumen quality (albumen height, Haugh unit, meat, and blood spots), e.t.c. (Bain et al., 2016; Duman et al., 2016; Liu et al., 2018; Bhattacharya et al., 2019). Several factors have been reported to impact egg quality and these include production systems and age (Yılmaz Dikmen et al., 2017; Rizzi, 2020), genetics (Bhattacharya et al., 2011; Lordelo et al., 2020; Rizzi, 2020), feeding (Abdel-Wareth and Lohakare, 2020;

Bejaei and Cheng, 2020; Marume et al., 2020; Esfahani et al., 2021), etc. Environmental enrichments are also noted to influence egg quality parameters in free-range hens (Bari et al., 2020a and 2020b).

### **Environmental Enrichments and Egg Quality Characteristics**

Bari et al. (2020b) determined no significant effect of environmental enrichment (novel objects that changed weekly and H-shaped perching structures) in indoor hen housing system until 16 weeks of rearing on egg quality parameters (shell reflectivity, egg weight, breaking strength, shell deformation to breaking point, albumen height, Haugh Unit, yolk color score, shell weight, and shell thickness). However, when the duration of environmental stressor imposed in the range area increased, egg quality parameters such as eggshell reflectivity, egg weight, breaking strength, shell deformation, shell weight, and yolk color score decreased, and albumen height and Haugh unit increased. Similarly, Bari et al. (2020a) identified no significant effect of environmental enrichments (novel objects and H-shaped perching structures) on average weekly egg weight, and proportion of abnormal eggs. However, the proportion of abnormal eggs and egg size increased with advancing hen age. In addition, egg weight, albumen height, Haugh unit, breaking strength, shell deformation, shell weight, or shell thickness were not significantly affected by enrichments, but all the above parameters decreased with increasing hen age. Moreover, a significant interaction between hen age and environmental enrichments for eggshell reflectivity and yolk color score was identified. It was argued that variations in egg quality are associated with how hens can adapt to environmental stressor of ranging behavior.

Schreiter et al. (2020c) stated that egg albumen consistency in laying period decreased after rearing different genotypes (Lohmann Brown classic, Bovans Brown, Lohmann Selected Leghorn classic, and Dekalb White) in environments enriched with either pecking stones and alfalfa bales. Schreiter et al. (2020b) observed that environmental enrichment with pecking stones and alfalfa bales material during rearing increased the percentage of cracked eggs in different laying hen genotypes (Lohmann Brown classic and Lohmann Selected Leghorn classic), and environmental enrichment during the laying period increased egg weights. However, when enrichment materials were continuously offered, the percentage of floor eggs increased in both genotypes. It was recommended that indoor environmental enrichment with pecking stones and alfalfa bales is not an appropriate approach for increasing the performance of laying hens.

### **Conclusions**

Banning conventional cages and increasing demand for improved welfare forced producers and scientists into new thinking which resulted in enriching the housing environment during rearing. The environmental enrichments used during rearing should not differ from the production system so that performance is not compromised due to the hen's limitation in coping with a completely new environment. It is established that the roles for rearing environment have a profound effect on pullet's

adaptability, physiological development, and performance as layer chickens (Janczak and Riber, 2015; Widowski and Torrey, 2018). A lot of changes are ongoing in the egg industry with respect to laying hen welfare. For example, phasing out cage systems will have considerable effects on global egg production since most of the world is still using conventional cages (Mench and Rodenburg, 2018). However, this should not be used as an excuse for failure to cope with the need to improve hen welfare. Bans come with export restrictions due to inability to reach the desired standard of a given product, hence producers and countries should always be updated on the latest developments regarding the shift from cage systems to cage-free systems (barn or floor, aviary, and free-range systems). There are also welfare concerns with cage-free systems (e.g., keel bone damage, feather pecking, and cannibalism due to increased stocking density, predation, high disease prevalence rate, increased mortality). However, advances in environmental enrichments will always try to reduce some of the detrimental effects of these systems. Interestingly, environmental enrichments in literature have proven to have benefits including reduced ranging time, better feather condition, lowered stress levels, better performance, boosting of immune system, etc. Although international bodies such European Union recommends enrichment of free-range outdoor area with pastures, appropriate pasture or plant species associated with improved hen welfare and egg quality characteristics have not been determined. On the other hand, studies regarding the effects of environmental enrichments on egg quality characteristics are insufficient. The available studies have observed no significant effect of environmental enrichments on egg quality traits. Therefore, there is a strong gap for identifying various environmental enrichments in different laying hen production systems that can enhance egg quality.

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