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Review

Laying hen strains and breeding system: A review of hen behavior and welfare, hen production performance and eggs quality traits in Africa and around the world

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ABSTRACT: The breeding system for laying hens has been the focus of scientific research for many years. During the last decade, new laying hen systems were rapidly introduced with the aim of improving the health of poultry and the welfare of consumers, producers and industries on the one hand and meeting the requirements on the other hand. The choice of the genetic type usually depends on the production performance and the color of the eggs. To this end, the aim of this work was to make a comparative review of the results obtained by different authors on effect of strain and farming system on production performance (egg production and mortality) and the characteristics of egg quality (egg weight, proportion of different parts of the egg, Haugh units, egg yolk color and carotenoid) of laying hens. Although the productive performance in ground systems is often low compared to the cage farming system, the eggs of the ground-based system have been proven by many studies to have the best nutritional properties. This review of literature on the use of different strains and different table egg farming systems could give a new direction to research.

Keywords: Egg quality, farming systems, laying hen, traits.

INTRODUCTION

Commercial egg production in industrial systems starts to increase rapidly in the United States after the second world war and much later in Western Europe and Africa. Its main features include containment facilities, illumination and artificial ventilation, a large number of highly productive battery-powered hybrid laying hens which provide a small space, the use of a complete ration (which may contain antibiotics, stimulants, hormones, artificial colors, etc.), the use of several hygiene conditions and cleaning products. This type of production provides ready-to-eat eggs in large quantities each year at low prices (Pavlovski et al., 2010), because the battery-based farming system has become the most popular egg-producing system in the world (Matt et al., 2011).

However, in recent decades, new laying hen systems were rapidly introduced to improve the health of poultry and the well-being of consumers, producers, industries and environmental requirements (Matković et al., 2007). It is also known that genetic origin affects egg production and determines the type of feed to be used (Reiter and Kutritz, 2001). Several breeders in the US are using improved soil fertility and healthy food production as benefits from this type of production (Hilimire, 2012). Henry (2002) reported that the most common breeding systems for laying hens are free-range and organic farming. Most of these farming systems include hens of different ages, subjected to a natural environment, fresh air, inorganic rocks (inorganic stone) and organic ration (plant and animal bases) of the degree that can allow increase in their daily nutritional requirements by 20% (Henry, 2002; Oberholtzer et al., 2006). In addition, birds are exposed to environmental climatic factors for both pest and predator attacks.

Some countries have already achieved a significant percentage of eggs from alternative livestock systems. Sales of organic eggs in the US have grown at a 20% annual rate since the 1990s, suggesting that the organic egg market is the fastest growing part of the organic agriculture sector (Oberholtzer et al., 2006). Among European countries, Italy has the largest market for organic products, followed by Spain (Mesías et al., 2011).

Three types of systems may involve the use of hybrid or local livestock adapted to existing environmental conditions. The genetic type used often depends on the color of the eggs. White leghorns are among the most popular and productive layers, while Rhode Island Red comes in second and produces most brown eggs in the US (Burbaugh et al., 2010). Hilimire (2012) reported that Plymouth Rock and Ameraucanas are primarily used for the production of red-shelled eggs. The main problems associated with rearing commercial hybrids are strictly controlled rearing conditions in three types of systems including weak eggs, excessive heart attack, high incidence of congestive heart failure (ascites), poor foraging capacity and a low heat tolerance and also, producers are often discouraged from breeding these hybrids in alternative production systems.

EFFECT OF STRAIN AND BREEDING SYSTEM ON EGG PRODUCTION

Egg production is one of the most important production characteristics of laying hens. It is equivalent to the number of eggs laid per year expressed as a percentage. A large number of researchers have studied this parameter through different farming systems. Anderson et al. (2007) revealed that there are statistically significant differences between egg production for brown Hy line layers reared in cage and ground respectively. Castellini et al. (2006) compared white caged Leghorn individuals in an organic and inorganic system. Birds in organic systems showed a low rate of egg production as controls (organic 63.4%, organic-plus 61.4%, control 74.1%). This difference is probably due to the high motor activity and simultaneously to the low energy and protein intake that is diluted by grass consumption mainly in the batch of organic-plus subjects. In addition, compared to the control, the spawning rate of organic birds is much more affected by seasonal conditions (temperature and photoperiod). A similar experiment using Ancona laying hens was conducted by Mugnai et al. (2009) which led to similar results (spawning rate: organic 60.6%, organic plus 59.6%, control 70.9%). Differences in productive performance between the cage system (80.82%) and the free-range system (72.88%) were obtained by Senčić and Butko (2006) with brown Lohman breeding hens as well by Yakubu et al. (2007) who found better production in Brown and Brown Lohman caged (74%) than in litter (69%) in terms of spawning performance. Similar results were published by Suto et al. (1997) and by Flock et al. (2005).

A study conducted by Ferrante et al. (2009) revealed a similarity in nesting rates of Hy-line birds raised under organic and cage systems. The spawning peak was reached at 25 weeks and was higher in organic layers than in the cage layers (94.5% vs 93%), while 25 to 58 weeks, the lay rate was high among the organic layers caged subjects with a final result, however, being identical (86.40% vs. 86.35%). These results are different from those of Tauson and Holm (2001), who found 3% fewer eggs in chickens compared to caged subjects. This difference may be due to strong management in both fields of study. Barbosa et al. (2005) found no difference in spawning performance of Hy-line W36 and Brown Hy-line on litter and cage. Similarly, Basmacioğlu and Ergul (2005) found no difference in Babcock-300 and Isa Brown, both in litter and cage systems. Gerzilov et al. (2012) found no significant difference in conventional and litter-reared Isa Brown hens in terms of oviposition rate. Hetland et al. (2004) reported that enriched cage hens consume more feed compared to hens raised in conventional cages. Meanwhile, Elson and Croxall (2006) demonstrated that feeding is lower in hens maintained in an enriched cage compared to conventional cages. However, Valkonen et al. (2008) found no significant difference in enriched caged Lohmann and Leghorn on productivity and feed conversion. A study by Van Horne and Van Niekerk (1998) showed that feed conversion is less effective in the aviary and free range system compared to conventional system. In the alternative system, hens need to spend extra energy on producing heat and moving, which is often due to storage density and low temperature (Preisinger, 2000). Other studies conducted in several European countries indicate that the production of eggs in furnished cages is comparable to that obtained in conventional cages (Abrahamsson and Tauson,1997). In contrast, Pohle and Cheng (2009a) reported that hens reared in furnished cages laid more eggs at 40 weeks compared to conventional caged hens because of significant improvements in feeding levels behavior of well-being. These results found that some genotypes may perform better in conventional cage culture systems, while other genotypes may respond positively to litter-free soil.

EFFECTS OF STRAIN AND REARING SYSTEM LAYING HEN MORTALITY

When analyzing mortality in chickens reared under ambient conditions, several adverse circumstances and conditions can cause birds to die (Bogosavljević-Bošković et al., 2012). In a free cage production system, the system itself, is a problem. Sossidou et al. (2011) showed high mortality in these production systems due to the broad spectrum of diseases and infections due to ambient conditions. Newcastle disease is reputed to be one of the most important diseases in the cage culture system. During the first manifestations of disease, nearly 80% of the subjects may die (Permin and Pedersen., 2002). Several main reasons for the movement of boxed poultry controlled the facilities included in diseases, parasites and predator attacks (Fanatico, 2000).

In all livestock systems, birds can develop abnormal behaviors such as stinging and cannibalism, which are the major causes of mortality with laying hens (Rakonjack et al., 2013). Blokhuis et al. (2007) studied different layer rearing systems and found that one-third of mortalities are caused by stinging and cannibalism, while Weitzenburger et al. (2005) found that cannibalism matters for more than 65.5% of the mortality of laying hens raised in various cages. Oden et al. (2002) found that rearing white feather genotypes can lead to reduced mortality of laying hens due to their susceptibility to stinging and cannibalism as primary causes of mortality. However, Van de Weerd et al. (2009) have recommended the opposite by proposing the breeding of non-white layers in a free rearing system in order to reduce the action of infectious agents responsible for mortalities. Hegelund et al. (2006) in his method showed that the system of organic production can be a potential cause of health problems, especially when the surroundings of the outdoor farm are not cleaned properly. Mortality is also high (11 to 18%) in large, organically raised flocks of poultry but can be reduced to 7 to 9% in smaller organic flocks (Berg 2002). When mortality exceeds 20% in the organic system, it is very often due to cannibalism. Given the threats associated with different housing systems, organic production with small numbers of birds is recommended (Bestman, 2004). A common problem encountered in poultry production in organic production is salmonellosis. The comparison of the battery system and the organic production system shows that battery-reared hens experience high mortality and are threatened by zoonoses and salmonellosis (Fiks-Van Niekerk et al., 2003). However, Van Overbeke et al. (2006) maintain that organic poultry production is more at risk from salmonellosis as in many other production systems.

EFFECTS OF STRAIN AND REARING SYSTEM ON EXTERNAL EGG QUALITIES

Egg weight is mainly affected by chick genotypes (Alkan et al., 2008). In addition, egg-laying performance is an important factor influencing egg weight. Castellini et al. (2006) reported that egg weight is negatively correlated with egg deposition rate. The most productive birds regardless of group and season produced lighter eggs. Other important factors are the age of the hens (Rizzi and Chiericato, 2010; Rizzi and Cassandro, 2009; Akyurek and Okur, 2009; Škrbić et al., 2011) and the energy of the food and its nutritional value, particularly the essential amino acid content and the level of protein (Elwinger et al., 2002; Krawczyk, 2009). Eggs produced in free-range systems have higher average weights than those raised in battery and conventional cages (Hughes et al., 1985; Hidalgo et al., 2008). Hughes et al. (1985) found that differences in egg weights may be due to changes in environmental temperatures in the box or in cage systems. However, Senčić and Butko (2006) obtained higher weights with layer-grown lohman brown hens (62.40 g) compared to those raised in cages (60.50 g). On the contrary, several authors have found that the average weight is low for layers reared in hut. Krawczyk (2009) attributes this result to the fact that animals can not satisfy their protein requirement in box breeding. Pištekova et al. (2006) found that Isa Brown layers raised on litter lay heavier eggs (62.02 g) than those raised in cages (60.63 g). Yakubu et al. (2007) found high weights eggs with Brown Bovans and Lohman Brown layers raised in cage systems compared to litter grown. Minelli et al. (2007) reported that the farming system itself, has a crucial impact on the weight of the egg; moreover, the effect of the ration is much more significant. Different farming systems have considerable effects on egg quality, including their physicochemical properties (Trziszka et al., 2004; Giannenas et al., 2009; Matt et al., 2009). Hidalgo et al. (2008) compared eggs purchased from supermarkets from different farming systems and found differences in shell percentage.

Another issue is the dirt of the eggshell and the microbiological condition of the shell. Dirty eggs have been found in litter systems compared to conventional cage systems (Leyendecker et al., 2001a), which may be due to nests or litter. Comparison of conventional cages and furnished cages shows that dirty eggs are less common in the furnished cage system (Abrahamsson and Tauson, 1997). However, De Reu et al. (2009) do not observe significant differences between the percentage of dirty eggs from furnished cages and conventional cages. Tauson et al. (1999), who compared three production systems (conventional cages, aviary and soil) and two bird genotypes (Lohman Selected Leghorn and Lohman Brown), found no differences in soil contamination. Eggs produced in different housing systems of Lohman Brown hens, but the eggs produced by the Lohman Select leghorn hens on the ground are less dirty than those of Lohman Selected Leghorn produced by the hens raised in the cage and in the aviary system. Protais et al. (2003) and De Reu et al. (2005) have shown that aviary egg shells are more contaminated with aerobic bacteria compared to egg shells in the cage system (furnished and conventional cages). De Reu et al. (2009) also counted fewer bacteria on furnished cage egg shells compared to egg shells obtained in the alternative system (4.75 vs. 4.98 cfu/shell).

However, the same authors did not find significant differrences with respect to the percentage of enterobacteria on eggshells between cages and alternative systems. Wall et al. (2002) compared conventional cages and furnished cages, found significant differences between the percentages of enterobacterial contamination counted on eggshells (12.3% in furnished cages versus 5.8% in conventional cages). Schwarz et al. (1999) reported that outdoor hen eggs are characterized by higher aerobic bacterial contamination compared to conventional cage eggs. However, De Reu et al. (2005) found no differences between negative grams of bacteria found on egg shells produced in conventional cages, furnished cages and aviaries. De Reu et al. (2009) reported that this bacterial contamination of eggs is determined not only by the system of production but also by the organization and management of the farm.

Wall et al. (2002) and Guesdon and Faure (2004) found that the number of cracked eggs was greater in furnished cages than in traditional cages. The eggs in the furnished cages is small and the eggs can go into one or the other. Meanwhile, Leyendecker (2003) showed a lower proportion of cracked eggs in furnished cages compared to conventional cages. In addition, the different inclinations of the cage floor can influence the number of cracked eggs (Valkonen et al., 2008). Similarly, De Reu et al. (2009) found a higher percentage of cracked eggs ($p < 0.01$) in furnished cages (7.8%) compared to an alternative production system. Guesdon et al. (2006) showed in their study of different hen housing systems that the proportion of cracked and broken eggs was higher in furnished cages (15.4, 19.6%) compared to standard cages (8.1, 12.2%). Hidalgo et al. (2008) found no significant differences in the quality of the shell of eggs produced in cages, in the open air and in organic systems. According to Pohle and Cheng (2009a), the Leghorn Blanc W-36 housing system reared in conventional, 19-week-old cages has no effect on shell thickness. Evidence previously observed shows that the production system has no conclusive effect on the number of dirty and cracked eggs, while the highest bacterial contamination of shells is characteristic of alternative systems.

EFFECTS OF STRAIN AND REARING SYSTEM ON INTERNAL EGG QUALITIES

Haugh unit is the objective measure of the quality of the egg based on the logarithm function of the albumen's height and the weight of the egg. Several factors may influence the Haugh unit: storage time and temperature, age of the hen, breeding system, strain and diet (dietary protein, essential amino acid composition e.g. lysine, methionine, food enzymes, protein sources), disease, supplements (ascorbic acid and vitamin E) and artificial exposure to ammonia (Roberts, 2004).

Carotenoids are natural pigments found in egg yolks. They give it the yellow color that can range from very pale yellow to bright dark or orange. Carotenoids represent less than 1% of egg yolk lipids mainly composed of carotene and xantophyll (lutein, cryptoxanthin and zeaxanthin). The total concentration of lutein and zeaxanthin is ten times higher than that of combined cryptoxanthin and carotene (Shenstone, 1968). Lutein xantophila and zeaxanthin have been of great interest since it is known that an increase in the nutritional intake of both components can prevent adult macula degeneration (AMD) and cataract formation in adulthood (Schlatterer and Breithaupt, 2006).

Economically, color is very important because it is a quality criterion for the consumer (Matt et al., 2011). The intensity of egg yolk is measured using the Roche scale. A dark color is much appreciated by consumers in different countries, for example in Australia, the preferred yellow color is 11 on the Roche scale (Roberts, 2004).

EFFECT OF STRAIN AND SYSTEM ON HEN BEHAVIOR

Among the factors that influence hen behavior are the housing system (Oden et al., 2002, Anderson et al., 2004, Whay et al., 2007), the density of occupancy (Albentosa et al. 2007), and the microclimate (Herbut et al., 2002, Prescott and Wathes, 2002). According to Weeks and Nicol (2006), the well-being of hens raised in conventional cages is compromised by the lack of nests. On the other side, enriched cages have nests and swims that allow birds to express their natural behavior such as nesting and swimming (Tauson, 2002). Yue and Duncan (2003) observed frustration and stereotypy of birds unable to use nests. Appleby et al. (2004) reported that birds have a strong instinct for finding a nest to lay eggs. Pohle and Cheng (2009b) observed that 25 to 41% of the birds analyzed used perches during the day. Appleby (1998) reported that approximately 80% of birds used perch at night. Also, Duncan et al. (1992) reported that 99% of chickens used approximately poles during the night. Pohle and Cheng (2009b) and Appleby et al., (2002) also found that birds prefer litter for pecking, resting and feathering by sandbaths. However, a sandbox can positively affect other forms of behavior such as pecking, feathering by sandbath and resting. Bird activity increases with large numbers per group, when the total size of the cage increases (Carey et al., 1995). However, cages with perches make birds less active (Matsui et al., 2004). Johnsen et al. (1998) reported that caged birds take longer to eat compared to aviary birds.

The systems of outdoor poultry production are suitable at present and are becoming more and more popular. This aviary housing system has a potentially positive impact on wellbeing because it allows them to perform natural behaviors such as moving, scraping, pecking, foraging and feeding (Mahboub et al., 2004, Tuyttens et al., 2005). Freire et al., (2003) found that for a large number of raised hens, the outdoor system can have a positive effect on bird welfare by reducing their aggressive behavior. However, according to Hegelund et al. (2006), this production system can cause health problems, especially when it is not used properly. Green et al. (2000) reported that the frequency of birds that eat in the outdoor system increases during hot, sunny days. Also, Weitzenbürger et al. (2005) reported that cannibalism is a major problem in birds raised in both conventional and alternative production systems. They also reported that the protection of the outdoor system from predators is inadequate, which often causes strong stress responses and makes birds less passionate about using them. Shimmura et al., (2008) did not observe the increase in the number of birds eating and cannibalism in birds raised outdoors. On the contrary, they believe that this type of farming system traps birds and prevents them from expressing their natural behavior. Mahboub et al. (2004) and Bilçik et al. (1999) reported that an increase in the number of birds per flock makes them more aggressive. Väisänen et al. (2005) show that shown that chicken lines have a lower capacity and cope with disturbances within their social group compared to their ancestors. Meanwhile, Anderson et al. (2007) believe that, in the long run, the reproductive genetic selection of the egg-type will make firm to enhance production parameters but will have no impact on the behavior of the offspring in the next cycles of production.

Important factors affecting bird behavior are also their genetic origin (Nielsen et al., 2003; Mahboub et al., 2004) and herd numbers (Reiter and Bessei 2000; Zeltner and Hirt 2003). Mahboub et al. (2004) showed differences in the behavior of two commercial hen lines. LSL (Lohman Selected Leghorn) hens were characterized by more movement on grassland but spent less time compared to Lohman Traditional hens. According to Nielsen et al. (2003), breeds of breeds kept in the open-air system frequently use the area around the farm and show much greater movement compared to hens of commercial lines that spend more time in the field to lie down and to feed.

In summary, avian behavior depends largely on the housing system. Hens raised in enriched cages and with outdoor access easily express their natural behavior which has a favorable effect on their well-being. Bird behavior is also determined by their genetic origin.

EFFECT OF STRAIN AND SYSTEM ON THE WELFARE OF HENS

According to Appleby et al. (2004), conventional cages do not provide the opportunity for birds to experience all of their freedom that is at the root of animal welfare and with the major consequences of preventing birds from expressing their natural behavior. Kopka et al. (2003) and Leyendecker et al. (2005) stated that, furnished cages improve hen well-being by reducing stress, aggression and stitching, and improve bone mineralization. However, Guesdon and Faure (2004) did not show a salutary effect on the welfare of birds reared in furnished cages compared to birds reared in traditional cages. Comparing conventional cage enriched, Barnett et al. (2009) found that herd size and space have a small effect on bird welfare while cage material (perch, nest sand bath, nest) has no influence on the well-being of birds and on measured physiological parameters, although it has a positive effect on bone strength. The presence of leg deformities in hens housed in furnished cages is likely due to the use of excessive perch, which may be a problem in this type of cage (Vits et al., 2005).

The open-air production system has a positive effect on the well-being of birds as it allows them to express their natural behavior such as moving, scratching, pecking, foraging and eating (Mahboub et al., 2004; Tuyttens et al., 2005). The use of the outdoor system not only boosts bird immunity, but helps them reduce their stress during rearing (Bestman et al., 2003). The production system also has an effect on leg diseases. The strength of bone fracture is less in conventional cages than in alternative cage systems (Leyendecker et al., 2001). By comparing conventional cages with furnished cages and aviaries, Leyendecker (2003) has shown that the force of the humerus is considerably higher in the furnished cages compared to conventional cages, but it was not greater than in the aviaries. In furnished cages, the increase in the number of birds raised in a cage can negatively affect the plumage (Appleby et al., 2002; Hetland et al., 2004; Weitzenbürger et al., 2005). Other research provides evidence that perch-equipped cages and litter bedding improve the plumage of hens (Abrahamsson and Tauson, 1997). The length of the claw is also dependent on the production system. In alternative production systems, birds have an opportunity to equalize their claws by moving and scratching the litter, which is different from hens raised in conventional cages where the length of the claws increases the risk of injury (Vits et al., 2005) and weakens the movement. This problem has been solved in partially furnished cages, although the views on this matter are divided. The system of production has a considerable effect on the well-being of the bird. It appears that free-range diaper systems are better at providing high levels of well-being because they reduce the stress of livestock birds while they are empowered to perform their natural behavior.

CONCLUSION

This review emphasis the need for additional research and observations has shown differences in the adaptability of different breeds of hens raised in different production systems. This will make it possible to optimize housing conditions in accordance with the principles of well-being and to make an appropriate choice of species or breeds in commercial lines to maximize economic and production outcomes; and to have hens resistant to the stress of production. The system of production of organic poultry is another matter and its principles are prescribed by separate regulations.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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