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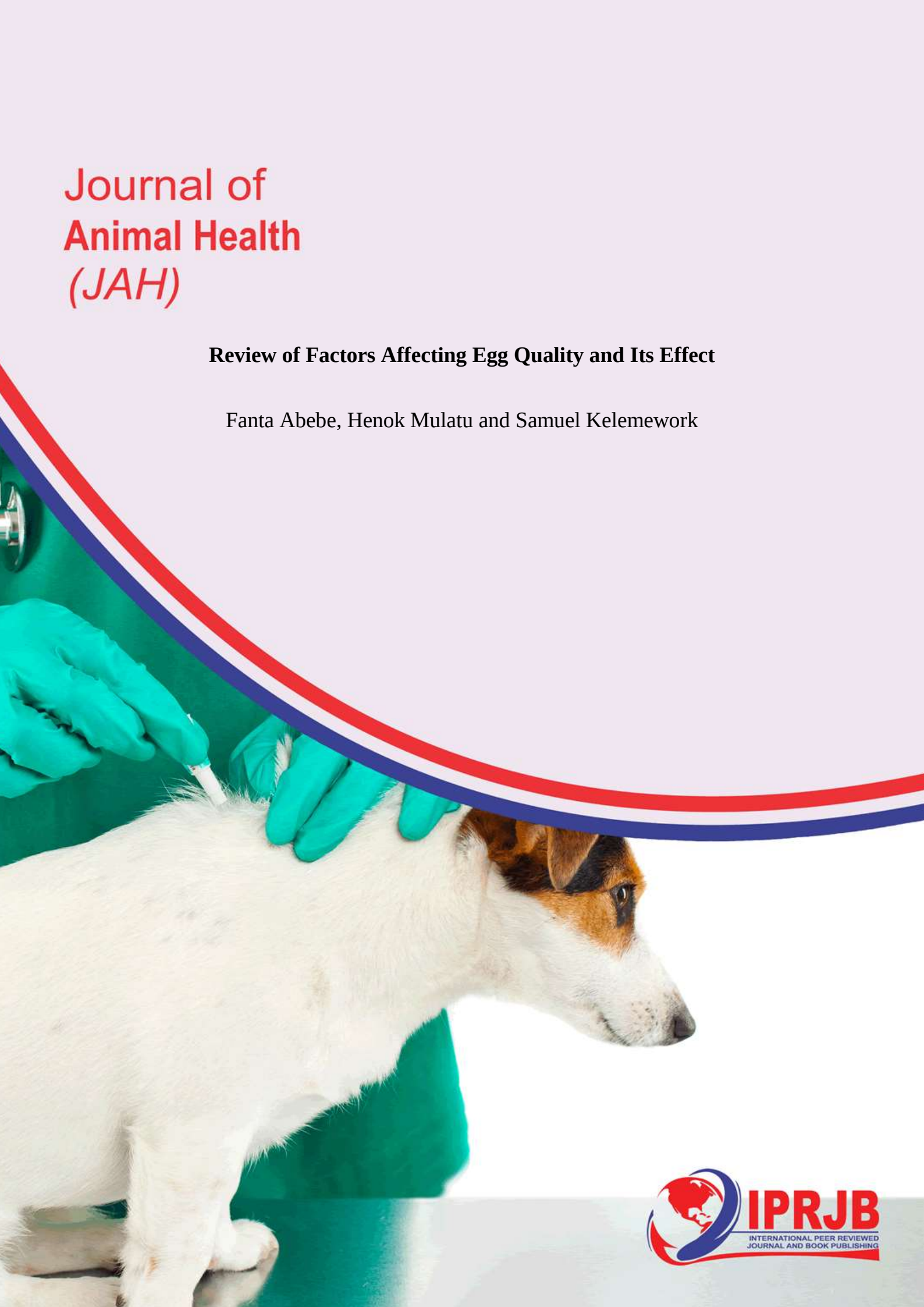

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Review of Factors Affecting Egg Quality and Its Effect

Fanta Abebe[1], Henok Mulatu[2]*, Samuel Kelemework[3]

[1,2] Habro District Livestock and Fisheries Development Office, Gelemso, Ethiopia
[3] Goba koricha District Livestock and Fisheries Development Office, Komona, Ethiopia

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Abstract

Purpose: Global commercial egg production, it is estimated that over 75% of hens are reared in cages but trends are emerging for maintaining layers in animal-friendly systems. The alternative systems have focused on developing better animal welfare and behaviour for laying hens.

Methodology: The study adopted desktop literature review.

Findings: Egg quality is an important factor influencing consumer purchase of eggs eggshell quality is one of the critical factors affecting overall egg quality before and after harvest. The quality of eggs is affected by some factors of both internal (genetic influences, age of the hen, laying cycle stage) and external nature, such as the nutritional level, microclimate parameters, and the system of management and housing system selected is economically important and also eggs are used in many food preparations and many industries the effect of some of these factors such as disease has been known for a long time while other factors such as certain drugs have been studied only in the past year or two. Certain drugs serve a very useful purpose when used for the purpose for which they were intended but when inadvertently fed to laying chickens may have disastrous effects.

Unique Contribution to Theory, Practice and Policy: promoting awareness to producers, consumers, and food processing industries to Ensure Food Safety of Eggs by applying proper hygiene practices in egg production and processing. Food poisoning special care is needed with handling and preparing fresh eggs or egg products; frozen, liquid, or dried egg products for consumption.

Keywords: *Egg Quality, Eggshell Quality, Environmental Factors, Storage*

INTRODUCTION

The egg is an important food in the human diet due to its high protein content, easy preparation and wide availability in the market, and low price compared to other sources of protein of animal origin such as meat and milk (Mendoza-Rodríguez et al., 2016). Eggs are a common food in every diet and are used in many basic and formulated preparations. Eggs are affordable and nutrient-dense food items, containing high-quality protein with low levels of saturated fatty acids, and are rich in several micronutrients including vitamins and minerals, some of which (vitamin E, carotenoids) are reported to have antioxidant properties(Nimalaratne, 2015).

The global production of table eggs has increased by 24.4% over the past decade, bringing production to 76.7 million tonnes in 2018, which is expected to increase further because of the high demand for animal-originated protein (FAO, 2021). In Ethiopia, the evolution of the poultry sector (in recent times) has highlighted the growing importance of small and medium-scale producers residing in urban and peri-urban areas (FAO, 2008).

Eggs are an appropriate first complementary food and feeding young children just one egg per day can have dramatic effects on their growth and micronutrient status. The egg is a very perishable article of food. Eggs are one of nature's most nutritious and economical foods. The income of the producer depends on the egg reaching the consumer with as much of its original quality as possible. To avoid contamination and food poisoning special care is needed with handling and preparing fresh eggs or egg products; frozen, liquid, or dried egg products for consumption, as per the guidelines (USDA,2013). The quality of the egg is never improved after it is laid. It is lowered very quickly by many factors of management and by being exposed to high temperatures and low humidity. Many factors can influence egg quality and appearance. These factors will vary depending on the housing environment, genetics, drugs, feed ingredients, or chemicals used in agriculture. Any farmer who produces a surplus of eggs that must enter the channels of trade should provide suitable farm storage holding conditions for preserving the original quality of the eggs.

The objective of this review is:

- To over view prominent causes of egg quality defects
- To over view the best way of keeping egg quality to consumer without deterioration in their quality
- To highlight management and improving the egg quality for producers, consumers, food processors, and stockholders

LITERATURE REVIEW

Egg Quality

Egg quality is defined as the characteristics of an egg, which affect consumer acceptability. Moreover, based on these quality parameters many egg-grading methods have been developed worldwide (USDA, 2000; Dudusola, 2010). Egg quality refers to various standards that define both external and internal quality. The internal quality is focused on the yolk height, yolk color, albumin viscosity, and Haugh unit. In contrast, the external quality refers to the eggshell thickness, egg width, height, and cleanliness (Coutts and Wilson, 2007). Egg quality is an important factor influencing consumer purchase of eggs. In recent years, due to

increasing awareness, consumers preferred to buy eggs with firm albumen, dense colored yolk, large size, and good quality (Samiullah S, et al., 2014). An increasing number of consumers are recognizing the health benefits of egg proteins, vitamins, and minerals. One of the most important aspects for consumers when choosing food is that the product is safe and healthy to eat (Li.T.; Bernard et al., 2017).

The egg quality comprises some aspects related to the shell, albumen, and yolk, and can be divided into external and internal quality. The internal quality is based on the air cell size, albumen, yolk quality, and the presence of blood and meat spots. All egg quality characteristics are affected by several factors including age and genotype of the hen, nutrition, type of rearing system, and the time of oviposition (Ahmadi and Rahimi, 2011; YANG et al., 2014).It has been reported that the external and internal characteristics of an egg mainly depend on the breed and its duration of storage (Tumova et al., 2007).

External Egg Quality Characteristics

The egg is a closed box with an external structure suitable to ensure its internal quality. This box is composed of CaCO3 (98%) in a polycrystalline structure in parallel layers forming the mammillary knob resulting in over 8000 pores serving for gas exchange inside and outside of the egg (NYS et.al., 1999). Among external characteristics; cleanliness of the shell, soundness of the eggshell, shape, egg weight, shell weight, and freshness are the most important characteristics in the marketing and preservation of eggs (Hrncar et al., 2014).

Eggshell quality: Eggshell quality is described by its actual weight and weight ratio, thickness, and strength. It is clear that the essential biological factors affecting eggshell quality, as well as overall egg quality, are internal and external/environmental. Significant differences in eggshell quality stem from the breed, line, and family classification of hens were recorded (Z h a n g et al. 2005). The external egg quality traits include shell thickness which is a measure of the shell strength mainly for the breeder flock incorporated and this is assessed to reduce eggshell breakages (Bekel et al., 2009; Alewi et al., 2012). Together with the improved social and welfare levels, egg quality is also becoming a significant issue for consumers worldwide. Egg preference and consumption value vary from one person to another. All of the factors that influence egg preference and acceptability affect egg quality parameters. Eggshell color is among the factors influencing egg preference by consumers (Hooge, 2007). It has been noted that the quality of table eggs worldwide, costs the egg industry many millions of dollars annually. Thus, the production of good eggshell quality is important to the economic viability of the global egg industry (Ahmad and Rahimi, 2011).

The Internal Egg Quality

Internal factors and functional quality parameters such as relative viscosity, foaming, gelling, yolk index, Haugh index, and chemical composition, firmness, free from foreign matters in yolk and albumen are important for the egg products industry (Duan et al . ., 2018; Sheng et al.,2018). The internal quality of the egg begins to decline as soon as the egg is laid. The management and nutrition of the hen do play a role in internal egg quality, egg handling and storage practices do have a significant impact on the quality of the egg reaching the consumer (Gerber, 2012). As regards the internal egg quality characteristics, thick albumen is quite an important measure of the freshness of an egg. Eggs stored for a long period lead to the denaturation of albumin and thus the albumin is usually watery (Meseret, 2010). Then, the eggs were broken and internal egg quality included yolk weight and percentage,

yolk index, yolk color, albumen weight and percentage, Haugh unit score, and blood and meat spots; these parameters were determined according to (Abd El-Rahman and Attia, 2002). Yolk color is one of the most important parameters of egg quality, which is related to market requirements in commercial egg production. In developing countries, customers prefer yolk containing a high pigment of yellow-orange colors (Leeson and Summers, 2008).

Albumen quality: As regards the internal egg quality characteristics, thick albumen is quite an important measure of the freshness of an egg. Eggs stored for a long period lead to the denaturation of albumin and thus the albumin is usually watery (Meseret, 2010). During storage, some well-known physical and chemical modifications take place. These are the thinning of the thickness of albumen and mainly the increase of albumen caused by the loss of carbon dioxide from the egg through the pores in the shell. A rapid loss of CO2 occurs particularly with the albumen, leading to a decrease in quality until the state of gas balance is reached between the inside. Concerning the results of the albumin index, it was reported by (Akyuret and Okur, 2009; and Jin et al., 2011), who reported that the albumin index was affected by storage periods and temperature. A decreasing trend of viscosity was observed with increasing storage period regardless of the type Viscosity of the village chicken egg was significantly higher than that of commercial chicken eggs. The rheological property of the egg albumen is an important quality attribute that determines the other functional parameters such as emulsifying ability, and whipping and gelling properties of the egg. Those are important in the egg products industry (Kemp et al., 2010).

Yolk quality: Yolk color is one of the most important parameters of egg quality, which is related to market requirements in commercial egg production. In developing countries, customers prefer yolk containing a high pigment of yellow-orange colors (Leeson and Summers, 2008). Alfalfa meal is rich in beta-carotene, xanthophyll and flavonoids, antioxidants, and other unknown growth and reproductive factors, and plays a role in the color of the egg yolk (Waheed,2016). According to (Jacob et al. 2000), the yolk quality of eggs is determined by the yolk color, texture, firmness, and smell of the yolk. The yolk of a freshly laid egg is round and firm. The pigmentation of the yolk is basically due to the presence of xanthophylls in the diet received (Desalew, 2012; Aberra et al., 2012). Green grass during scavenging might be responsible for carotenoid deposits in the yolk, which improves the yolk color. Among feed ingredients, only supplemented maize contributes to improved color intensity of the yolk. Thus, if a hen has access to green grass or supplemented feed ingredients containing carotenoids/xanthophylls, it will be enough to give the yolk the color preferred by consumer (Zaman et al ., 2004).this also agri with Abiodun, 2014, The color of the egg yolk is due to the accumulation of pigments (Carotenoids) coming from the diet of the hen. Green materials such as corn, corn gluten, and marigold are good sources of yellow color pigments

Haugh Unit/Quality: HU is a measure of egg quality, particularly albumen quality. It signifies the freshness of an egg. HU is calculated from the height of the albumen and the weight of the egg (Coutts and Wilson, 1990; Sekeroglu et al., 2008).

Factors Affecting of the Egg Quality

The Genetic and Environmental Factors

Many genetic and environmental factors affect both the internal and external quality of eggs. Today, alternative systems have become more important and the effect of these systems on egg quality parameters needs to be determined (Van Den Brand H..al., 2004 ,Aberra et al.,

2012). The quality of eggs is affected by many factors of both internal (genetic influences, age of the hen, laying cycle stage) and external nature, such as the nutritional level, microclimate parameters, and the system of management selected is economically important. Eggshell quality is one of the critical factors affecting overall egg quality before and after harvest. The higher weight, broken eggs (%), and lower eggshell quality of eggs from source could be attributed to the older hens' age of this group as the hens were in production for 18 months when eggs were collected from the market than that of the other groups 6-10 months. On the other hand, the values of eggshell quality criteria found herein are within the range of those retrieved by several authors (Kiiskinen and Helander, 1998; UDSA, 2000; Ahmadi and Rahimi, 2011; Al-Harthi and El-Deek, 2011; Alsaffar et al.,2013). However, the amount of thick albumen and Haugh units, as indicators of egg quality and freshness, depend on the origin, age, or nutrition, mainly on the laying date and storage time (Huang, Q. et. al., 2012).

Effects of Housing Systems for Laying Hens on Egg Quality

Egg quality could also be evaluated by the level of microbial contamination. The level of eggshell contamination with bacteria depends on the housing system and is related to temperature and humidity. A higher number of microorganisms were recorded on eggshells from alternative housing systems when compared to cages (De Reu et al., 2005, 2006). The higher bacterial contamination in eggs from alternative housing systems was caused by a higher probability of egg contact with feces or bedding material. This same result was reported by (Singh et al., 2009), who determined that eggs from cages had lower Escherichia coli and coliform contamination than those from nest boxes and the floor. The percentage of eggs laid in the nest and the disposition of the equipment (nest, perch, and scratching area) may significantly affect the bacterial load of the eggshell.

Generally, hens housed in cages are at a lower risk of infectious (Noormohammadi 2021) and parasitic diseases (Groves, 2021) than are hens housed in free-range systems. The increased disease burden experienced by free-range hens may increase their requirement for amino acids to support an upregulation of the immune response (Klasing, 2007).

Effect of Diet and Water on Egg Quality

The supply of feed to laying hens is the most significant cost of egg production and diets are formulated to meet the nutrient requirements of the hen at least cost. The modern bird has been selected for high productivity (Underwood et al., 2021) Alfalfa (Medicago sativa L.) is a valuable source of n-3 fatty acids, vitamins, carotenoids, and minerals, which is reflected in the meat and eggs of poultry (Englmaierova. et al. 2019). Egg composition is relatively consistent in terms of total protein, essential amino acids, total lipids, phospholipids, phosphorus, and iron. Other components such as fatty acid composition, mineral contents, vitamins, carotenoids, antioxidants, and cholesterol content are influenced by the diet of the hen and are more variable. These Component percentage differences may be attributable to strain, age, and environmental conditions (Rizzi, and Marangon, 2012).

The intake of water and feed are directly related; hens that drink less water will also consume less feed, and, subsequently, egg production declines. Presumably, current high-producing laying hens have higher metabolic demands for water than did earlier layer strains. Water intake is a sensitive indicator of bird health and, therefore, monitoring the water intake of a flock is a useful guide to changes in bird welfare (Leeson and Summers, 2008, Rault et al., 2016).

Minerals such as Ca, P, and vitamin D are the primary factors affecting the eggshell quality of layers (Attia et al., 1994, 2009). Differences in eggshell quality of laying hens could be expected due to concentrations of dietary calcium, phosphorus and vitamin D3, Mn, strain, age, husbandry and management of hens (Attia et al ., 1994; Zita et al.,2009), water quality, dietary protein levels, fat/fatty acid contents, health status and environmental stress of layers (Attia et al.,2009; Ahmadi and Rahimi,2011; Alsaffar et al., 2013).

The Direct or indirect shell strength measures (such as shell thickness and weight, shell percentage and density, shell deformation, or resistance to breakage) also seem to be more dependent upon other factors, such as genetics, age, feed levels, or even egg size, than on the housing system itself(Karcher et al., 2015). The contrasting results found in the literature do not support a clear influence of the housing system on shell strength.

Effect of Storage Time, Temperature, and Handling on Egg Quality

The egg quality is influenced by both genetic and environmental factors, hens laying substandard eggs should be culled besides the management of the hens can help in improving the quality of eggs (Aberra et al.,2012).According to(Samli et al., 2005) storage time and temperature appear to be the most crucial factors affecting albumin quality or Haugh unit. A decrease in bacterial contamination on eggshells in the winter period was probably caused by low temperatures. Seasonal influence on eggshell contamination is also evident from the results of experiments by (Mallet et al., 2006). In Sudan, most egg dealers (producers, wholesalers, and retailers) do not handle and store their eggs properly when transporting them to consumers; instead, they may sell them to shops or open markets where storing conditions are not controlled. The improper storage situations under these trading facilities may lead to rapid deterioration in egg quality. On the other hand, rough handling can cause smell, and almost invisible cracks in the shell that make the egg more prone to bacterial infection (Codex, 2001).

A negative correlation between daily feed consumption and temperature in poultry was detected. As the temperature of the poultry house increased, feed consumption reduced. In addition, the feed conversion ratio also decreased. The reverse trend was observed in lower temperatures. If environmental temperature is allowed to exceed normal ranges, then egg production, egg size, and growth will be negatively affected. These factors along with others affect the birds' metabolism which in turn is responsible for the output of eggs, meat, and body heat to maintain normal physiological processes and functions. Environmental stressors such as hot temperatures, high air humidity, etc., may affect the bird in an additive manner if these stressors are imposed concurrently. These stressors can negatively affect a hen's growth performance, feed intake and efficiency, and physiological status (Talukder. et al., 2010). All these have a direct relationship with the quality characteristics of shell eggs produced by laying birds.

In commercial laying hen facilities, storage temperatures play a significant role in delivering the eggs to the consumer at peak laying freshness. Following the laying, based on storage temperature and duration, CO2 and weight losses, increased albumen pH levels, and decreased albumen weight and heights are observed in eggs (Yılmaz and Bozkurt, 2008). Prolong storage time is caused by decreased yolk color due to the entering of water into the yolk through a vitelline membrane. Water entering the yolk dissolves the yolk pigments resulting in a decrease in yolk color (Jones et al..,2001; Wardy, 2010).

Genetic (Breeds) and Age Factors

Genotype has a direct influence on egg weight and eggshell characteristics. Many studies showed that hens with colored feathers lay bigger eggs than hens with white feathers (Halaj and Grofík, 1994; Vits et al.,2005; Halaj and Golian, 2011).

The influence of the genotype on the egg weight is reflected more clearly in comparison of hens laying eggs with white or brown shells, which is related to the genetic origins of the hens(L e d v i n k a, and K l e s a l o v á, 2002). Eggshell quality is described by its actual weight and weight ratio, thickness, and strength. It is clear that the essential biological factors affecting eggshell quality, as well as overall egg quality, are internal and external/environmental. Significant differences in eggshell quality stem from the breed; line and family classification of hens were recorded. (Z h a n g et al., 2005) In addition, the embryonic development of the hen's egg is dependent on traits like egg weight, yolk and albumen weights, genetic line, and age of the hen (Onagbesan et al., 2007).

One of the main concerns is a decrease in eggshell quality as the hen ages, due to an increase in egg weight without an increase in the amount of calcium carbonate deposited in the shells. For this reason, the incidence of cracked eggs could even exceed 20% at the end of the laying period (Nys, 2001). These findings agree with those of (Riczu et al. . 2004), who found that eggshell quality parameters deteriorate with increasing hen age, except for eggshell weight, which increases with age.

Microbial Contamination and Residues

Foodborne illness can be attributed to improper food safety practices in the home (Redmond. et al., 2003) In the European Union more than half of all Salmonella outbreaks are linked to contamination in the home.

There have been numerous studies that have demonstrated that a significant proportion of foodborne illness can be attributed to improper food safety practices in the home (Redmond and Griffith, 2003). Consequently, an increased opportunity for food preparation and handling safety mistakes to result in illness (Byrd-Bredbenner. et al., 2013).

M.icrobial contamination of the eggshell depends mainly on the housing system, which is used for the rearing of laying hens and determines the environment in which the eggs are laid. It depends on the level of pollution on both the surface of the facilities buildings as on the well as feathers and feet of hens, and also on the concentration of microorganisms and dust in the air. Bacteria make up only a small proportion of airborne particles, but may negatively affect the initial bacterial contamination of the eggshell (D e R e u et al., 2005, 2008b)

Hence, the risk of egg contamination by pathogenic bacteria, especially S. enteritidis, is a major concern for egg production and egg product manufacturing industries(Baran and Jan 2011) Many other factors, such as cracks or dirt on the shell, dust concentration in the rooms or season, may also influence eggshell bacterial contamination (Mallet et al.,2010).

One of the most common sources of salmonellosis has been identified as raw eggs and egg products (Howard, Z.R.et.al 2012; OzFoodNet, 2015). Additionally, in 2011 the OzFoodNet working group demonstrated that 48% of all salmonellosis outbreaks could be attributed to eggs or egg-related products.

The chemicals relevant to food safety include environmental exposures to persistent organic pollutants such as dioxin pesticides, and heavy metals. The most widely chemical contaminations of eggs associated with free-range or organic flocks are increased levels of dioxin-like compounds (Holt et al., 2011). The hens' intake of dioxins from various sources leads to an increase in the dioxin content of eggs. These sources include plants, feed, soil, worms, and insects. Plants and commercial organic feed appear to be relatively unimportant as sources of dioxins, but not much is known about the noncommercial feed offered to laying hens in small organic farms or backyard flocks. Consumption of worms and insects and particularly ingestion of soil are important causes of high dioxin levels in eggs (De Vries et al., 2006).

The Economic and Public Health Importance of Egg Quality

The main actors in egg marketing are producers, collectors, traders or (wholesalers), local kiosks, shops and supermarkets. Urban markets followed by the nearest local market and farm gate are, in order of importance, the preferred outlets for egg marketing by producers (Moges et al. ., 2010b)

Egg quality is an important economic trait. With the extension of the laying cycle, the decline in egg quality during the late laying period, such as the increased % of cracks and the large variation in eggshell color, has aroused great concern (Bain. et.al.2016). It has been noted that the quality of table eggs worldwide, costs the egg industry many millions of dollars annually. Thus, the production of good eggshell quality is important to the economic viability of the global egg industry (Ahmad and Rahimi, 2011) production costs are important for producers, and in alternative systems such as enriched-cage or no-cage systems, production costs are high (Walker, A.W. 1998) Egg quality is an important factor influencing consumer purchase of eggs. In recent years, due to increasing awareness, consumers have preferred to buy eggs with firm albumen, dense colored yolk, large size, and good quality (Samiullah .S.et.al 2014).

Ethiopian consumers have a strong preference for eggs with a deep yellow yolk color. Very small-sized eggs from the scavenging local chicken with deep yellow yolk color fetch much higher prices compared to larger eggs of improved strains with pale yolk (Tadelle et al., 2003a). In North West Ethiopia, the price, demand, and supply of chicken are highly related to religious festivals, mainly Christian festivals.

Therefore, it is of great importance to understand the factors that affect eggshell quality and egg internal quality. The hen's egg consists of the yolk (30-33%), albumen (approximately 60%), and the shell (9-12%) (Stadelman . 1995). Worldwide, foodborne illness is a significant public health burden (Havelaar,.et.al.,2015) Global estimates indicate that every year there are just under 600 million cases, including 350,000 fatalities (Kirk, .et.al.,2015) One of the most prevalent causes of foodborne illness is salmonellosis(Gali et.al.,2013; Majowicz et.al.,2010,). One of the most common sources of salmonellosis has been identified as raw eggs and egg products. Globally, the primary causative agent for salmonellosis is Salmonella enteric serovar Enteritis (Howard, Z.R.; et al., 2012; OzFoodNet.2011).

In the European Union more than half of all Salmonella outbreaks are linked to contamination in the home (Byrd-Bredbenner et.al., 2013). There is general acceptance that eggs in the retail market have similar quality. The variability in the quality and nutritional values of eggs

has a significant impact on consumers' health; simultaneously, welfare and many other factors can affect egg quality. These factors include the breed and strain of layers(Zita et al., 2009; Kucukyilmaz et al., 2012). Another important human health risk related to egg consumption is the potential presence of residues of veterinary drugs because laying hens treated with pharmaceutical products can produce contaminated eggs (Goetting, V.et.al., 2011).

CONCLUSION AND RECOMMENDATION

Egg quality is very important because egg is one of the most valuable food item consumed by humans. Due to this high quality, eggs are used in many food preparations and industries, which makes them one of the factors that contribute to food-borne disease outbreaks. Bearing this public health importance in mind few efforts were exerted to secure their safe consumption for humans. This can be done through proper storage and efficient handling from the production areas to consumption centers. Eggs are one of nature's most nutritious and economical foods.

The quality of the egg depends on factors before the laying phase and after the oviposit ion. Hen´s health, feed safety, and environmental quality are intrinsic factors that define the quality of the laid egg. After oviposition, environmental conditions, grading and pack systems, processing, handling, and transportation start to have an influence, particularly on the shelf-life and internal quality of the eggs.

Based on the above conclusion, the following recommendations are forwarded;

- promoting awareness to producers, consumers, and food processing industries to Ensure Food Safety of Eggs by applying proper hygiene practices in egg production and processing
- To avoid contamination and food poisoning special care is needed with handling and preparing fresh eggs or egg products; frozen, liquid, or dried egg products for consumption.
- Producers must ensure that the product marketed complies with the regulations governing the safety of food products. Among other things, it requires them to adopt preventive measures and to use refrigeration during egg storage and transportation.

Consent for Publication

I fully agree that this paper can be published in our journal

Disclosure

The authors declare that they have no competing interests.

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