REVIEW ON CHICKEN EGG QUALITY DETERMINATION, GRADING AND AFFECTING FACTORS

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Abstract:

There is a lot of chicken population throughout the world from which 80 percent of them found in village poultry production system. This indicates the importance of village chicken production for the development of rural economy. As an example, in Ethiopia, total poultry production at country level is estimated to be 50.38 million and with regard to breed 96.9, 0.54 and 2.56 were reported to be indigenous, hybrids and exotic chicken respectively. External quality of an egg can be measured by egg size, shell color, shell breaking strength, shell deformation (destructive or non-destructive), shell weight, percentage shell and shell thickness whereas internal egg quality is measured by yolk color, air space and albumen quality. Grading of an egg is determined by interior and exterior quality of eggs. In this process eggs are examined for both interior and exterior quality before they are sorted according to their quality levels. These grades are: Grade AA and A eggs are nearly identical but, the main difference being that grade A eggs are slightly older than grade AA eggs. Grade B eggs have stained or abnormal shells, minor blood and meat spots. The parameters of both internal and external quality of an egg can be influenced by many factors, like: temperature, storage time, age of hens, nutrition and housing system. In developing countries, these factors are not well recognized as factors affecting egg quality due to poor knowledge of people on egg quality inspection. So; I reviewed this paper to enhancing the knowledge of developing countries on giving care for quality of eggs after reading paper online. Finally, effective and efficient management should be given for both egg and hen to obtain high quality product.

Key Words: Affecting factors, Egg Quality, Egg Grading,

Introduction

About 80 percent of total chicken populations are found in village poultry production system worldwide. This indicates the importance of village chicken production for the development of rural economy [1]. In Ethiopia, total poultry production at country level is estimated to be 50.38 million and with regard to breed 96.9, 0.54 and 2.56 were reported to be indigenous, hybrids and exotic chicken respectively [2]. An egg is a vehicle for reproduction and it also serves as a source of food for human consumption. The size and shape of eggs differs among the various species of birds, but all eggs have three main parts like yolk, albumen and shell. These three parts of the egg are separated from each other by membranes. The shell is separated from the albumen (egg white) by the shell membranes and the yolk is separated from the albumen by the yolk membrane [3] Egg quality is determined by its consumer acceptance with respect to several characteristics including surface area, egg weight, shell quality, Haugh unit (HU) and chemical composition It can be divided into internal and external quality [4]. The internal quality is based on the air cell size, albumen, yolk quality and the presence of blood and meat spots where as external quality is measured by egg size, egg shell color, shell breaking strength, shell deformation (destructive or non-destructive), shell weight, percentage shell and shell thickness. All egg quality characteristics are affected by several factors including age and genotype of hen, nutrition, housing system, disease, temperature, storage time, water quality and time of...
Egg grading is a form of quality control which is based on internal and external quality of eggs. When determining the grade of an egg, the factor with the lowest grade will determine the overall grade of an egg. Grades AA and A eggs are nearly identical, the main difference being that Grade A eggs are slightly older than Grade AA eggs. Grade AA eggs therefore have firmer, thicker whites that hold the yolks up high and round whereas the white of a Grade A egg is reasonably firm, meaning it spreads a little further when you break the egg into a frying pan. Grade B eggs have stained or abnormal shells, minor blood or meat spots [7]. In some developed countries, commercially produced eggs are graded simultaneously for exterior quality factor such as cleanliness and soundness of the shell and interior quality factor like that of white, yolk and size of air cell before providing it to market [3]. However, egg quality determination and grading systems are still not fully implemented to the intended rate world widely. Moreover, such practices are not followed in developing countries like Ethiopia. Therefore, the objective of this review paper is:

➢ To review on egg quality determination, grading and affecting factors

**Literature Review**

**General Characteristics of Chicken Egg:**

The chicken egg is a complex biological structure which is one of the most nutritious and versatile of human foods. An average egg weighs approximately 57 grams and the nutritive content of a large egg (~50 g of edible egg) includes: 6.3g of protein, 0.6g of carbohydrates, 5.0g of fat (including 0.21g of cholesterol). It consists of approximately 10% shell, 58% white and 32% yolk. The albumen of the egg is composed of the outer thin albumen and the inner firm or thick albumen. Neither the color of the shell nor that of the yolk affects the egg’s nutritive value [8, 7]. The egg is composed of many parts, namely: The shell, shell membrane, albumen and yolk. The shell of an egg has a rigid yet porous structure which has great resistance to the entry of microorganisms when kept dry and considerable resistance to the loss of moisture by evaporation. Inside the shell there are two membranes (inner and outer membrane). The inner shell membranes have direct contact with the albumen while the outer membrane lies just above the inner membrane. An air space or air cell is a pocket of air usually found at the large end of the egg interior between the outer membrane and the inner membrane (Figure 1). This air cell is created by the contraction of the inner contents while the egg cools and by the evaporation of moisture after the egg has been laid. The air cell increases in size as time passed.

![Figure1: Chicken egg parts](source: [10])
Factors Affecting Egg Quality:

For the egg industry worldwide, the production of eggs which are good egg quality is critical to the economic viability of the industry and problems with egg quality currently cost egg industry. Therefore, it is a great importance to understand the factors that affect egg shell quality and egg internal quality [11].

Diseases: Infectious bronchitis, a viral disease caused by a corona virus which attack the mucus membrane of the reproductive and respiratory tracts that may results to egg defects. It affects both egg shell and internal egg quality. Watery whites are very common and can persist for long periods after egg production returns. Also, an infectious bronchitis outbreak can result in a pale-colored shell eggs. However, other factors, such as stress, are also responsible for causing a pale-colored shell. Another disease which may affect shell quality is Egg Drop Syndrome (EDS). The disease is mainly characterized by a drop-in egg production early in lay, or by a sudden fall in production at a later stage in the laying period [12].

Storage Period and Environmental Temperature:
The effect of temperature (ambient and refrigerated) and storage time on egg quality, verified that the increase of storage time caused reduction in HU and egg weight because, of the continuous loss of CO2. Shell strength is one of the most important external quality parameters of an egg, usually dependent on egg shell proportion and thickness [13]. Differences in egg shell physical parameters are dependent, among other factors, on the rate and extent of mineral deposition in the egg shell [14]. High environmental or shed temperatures may also affect the feed (calcium) intake of the hen, thus resulting in a decreased availability of calcium for shell deposition. One week at 25 °C will reduce the Haugh Units (HU) up to the limit of acceptable freshness 70 HU, whereas one week at 8°C will result in eggs that are still very fresh 85 to 90 HU [15].

Nutrition: The provision of adequate nutrition containing minerals and vitamins are essential for good egg shell quality. Calcium and phosphorus are essential macro minerals with calcium forming a significant component of the shell and phosphorus playing an important role in skeletal calcium deposition for egg shell formation. Inadequate dietary phosphorus may cause demineralization of the skeleton in laying hen. The ratio of calcium to phosphorus in the diet is important as the level of phosphorus interfere with the absorption of calcium from the gut; resulting in poor shell quality [16].

Housing Systems: The type of production system may influence egg shell quality. For example, egg shell thickness varies according to housing systems (non-cage and cage housing systems) [17]. Which influence the behavior of hens, especially when hens in cages and non-cage systems are compared. Hens in non-cage systems will spend more energy on movement, which may result in smaller eggs or reduced yolk content and also contamination of shells with microorganisms is higher in non-cage systems since more eggs tend to be laid outside nest boxes and the interactions between active hens and bedding material increases dust in the atmosphere which is a carrier of microbes [18, 19].

Managements: Good managemental practices will help to reduce the number of dirty eggs which include frequent collection of eggs, regular replacement of litter material in nest boxes, regular maintenance and cleaning of cage floors and roll out trays. Overcrowding of hens, changes in the lighting programme, poor ventilation and inadequate water supply can contribute to increased incidence of shell defects associated with egg texture. Light influences bird behavior, metabolic rate, physical activity and physiological factors such as reproduction [20].

Age of hen: The single most important factor affecting albumen quality of fresh eggs is the age of the hen. As the hen become older, albumen quality decrease. The egg shell characteristics vary in different stages of laying hen age. Very young hens with immature shell glands produce shell-less eggs or eggs with a thin egg shell. Egg shell weight increased with the age of hen. For example, the heaviest egg shells (6.67 g) were found at the age of 56–60 weeks in comparison with 5.05 g at 20–24 weeks of age [21]. The increase of egg shell weight with aged hens is related to the increasing size of the egg and shell surface area. Egg shell breaking strength decrease with the age of hens; because higher plasma mineral contents are found in aged hens and decreased egg shell strength by 3.33 kg/cm2 in older hens in comparison with younger ones by 3.60 kg/cm [22]. As hen age increases, the intensity of pigment decreases. This may be due to decreasing production of pigment or increased surface area over which available pigment is distributed and also HU decreases at a fairly constant rate of 0.0458 units per day of lay as the hen age increase [23].
Determining External Egg Quality:
External egg quality is measured in many ways. Among many quality characteristics, external factors including cleanliness, egg weight and shell weight. It can also measure by egg size, shell color, shell breaking strength and shell thickness are important in consumer’s acceptability of shell eggs [24, 25]. The weight of eggs varies widely depending on many factors such as the breed, the age of the layer and environmental temperature. In Africa, the egg weight may range from 35 to 65 grams (g), while in Europe it may range from 45 to 70 grams (g). As a layer gets older the weight of the eggs increase [26]. Direct and indirect measurement of shell strength can be considered as mechanical and physical properties of egg respectively [27]. Direct method includes measures of shell breaking strength such as puncture force and shell weight whereas indirect methods include specific gravity, non-destructive deformation and the percentage of crack. Shell thickness is measured by millimeter (mm) using electronic digital caliber. A shell should be thick enough for the egg to withstand a reasonable amount of handling without breakage, because lower strength causes higher percentage of egg damage which increases economic losses [28,29]. The color of an egg shell is determined primarily by the genetics of the hens, thus white feathered hens lay white eggs and brown feathered hens lay brown eggs [30]. During the process of egg shell formation, the epithelial cells lining the surface of the shell gland synthesize and accumulate pigments. In the final three to four hours of shell formation these pigments are transferred to the viscous, protein rich cuticle. The quantity of pigment in the cuticle determines the color of egg shell [31].

Determining Internal Egg Quality:
The internal quality of an egg is determined by the composition of egg white, yolk and possible enclosures (flesh, blood), but also by the freshness since egg starts to age directly after laying. This aging impact can be measured using either destructive or non-destructive methods. The non-destructive method assesses the size of the air chamber and the destructive method measures the height of the thick albumen, with egg content on a flat surface, the so-called HU [32]. Albumen quality has a major influence on overall interior egg quality and it provides more protein than the yolk. Over half of the protein in whites is ovalbumin, although conalbumins, ovomucid, and globulins (including lysozyme, which is able to lyse some bacteria) contribute lesser percentages of protein in the egg whites. Thinning of the albumen is a sign of quality loss. [33]. Yolk quality is determined by the color, texture, firmness and smell of the yolk. Yolk color is a key factor in any consumer survey relating to egg quality. Consumer preferences for yolk color are highly subjective and vary widely from country to country. The primary determinant of yolk color is the xanthophylls (plant pigment) content of the diet consumed [30]. Yolk pigments are relatively stable and are not lost or changed in cooking. Sometimes there is a greenish ring around hard cooked egg yolks due to sulfur and iron compounds in the egg reacting at the surface of the yolk. It may occur when eggs are overcooked or when there is a high amount of iron in the cooking water. Although the color may be a bit unappealing, the eggs are still wholesome and nutritious, and their flavor is unaffected [3]. The inclusion of more than 5% cottonseed meal in a layer diet will result in olive or salmon colored yolks while the inclusion of certain weeds or weed seeds may results in green yolks. Both inadequate mixing of the diet as well as excessive mixing of the diet will also result in a heterogeneous feed and subsequent variation in the amount of xanthophylls consumed by each hen in the flock, this will result in egg yolk color not being uniform throughout the flock [20,34] The yolk of a freshly laid egg is round and firm; however, as the egg ages and the vitelline membrane degenerates, water from the albumen moves into the yolk and gives the yolk a flattened shape. Rubber yolks may be caused by severe chilling or freezing of intact eggs, the consumption of crude cottonseed oil or the seeds of some weeds. The depth of the air cell is the distance from its top to its bottom when the egg is held with the air cell up. In a fresh egg, the air cell is small, not more than 1/8-inch deep. As the egg ages, evaporation takes place and the air cell becomes larger and the egg is downgrade [35].
Egg Quality Grading:

Egg grading is a form of quality control used to divide an egg into a number of classes based on both internal and external qualities. The purpose of the egg grading is to sort the eggs into categories based on exterior quality factors such as cleanliness and soundness of the shell and interior quality factor such as albumen, yolk, air cell and possible abnormalities. By using candling and broken-out method, grading of an egg can be done. Egg shall be graded into 3 classes namely grade AA, A and B [26]. Grades AA and A eggs are nearly identical, the main difference being that grade A eggs are slightly older than grade AA eggs. Grade AA eggs have firmer, thicker whites that hold the yolks up high and round, whereas the white of a grade A egg is “reasonably firm,” meaning it spreads a little further when you break the egg into a frying pan. Grade B eggs have stained or abnormal shells, minor blood or meat spots [7].

Candling: Candling is used to judge interior egg quality because external appearance is not an accurate indication of overall egg quality. Each egg is graded on its individual merits of quality according to United States Department of Agriculture (USDA). Knowledge of the parts of the egg is essential to understanding candling and grading. Candling has the advantage of being non-destructive, rapid and automated (figure 3). A very simple form of candling is placing a candle in a dark room and positioning an egg in front of the flame and looking at the interior quality [3].

Figure 2: Official air cell gauge and method for measuring depth of air cell
Source: [3]
Broken-out Method: Break-out method of determining interior quality is a way for graders is develop their grading skills that enable them to make comparisons of broken out egg appearance with candled appearance. The most accepted and widely used method for determining albumen quality is measuring Haugh units. HU was calculated from two parameters; height of albumen (AH) and Egg weight (EW). To calculate HU, we can use this formula: 

$$HU = 100 \log (AH - 1.7 EW^{0.3})$$

where as to calculate albumen percent we can use; albumen percent = (Albumen weight/weight of the whole egg) x 100 [38]. The higher number of HU the better quality of eggs and the values ranges from 0-130. The HU ranked as grade AA: 72HU, A: 71-60HU and B: 59-31 HU [36]. When a fresh egg is carefully broken out onto a smooth flat surface, the round yolk is in a central position surrounded by thick albumen. The diameter of the thick albumen (top view) may give an indication of grade; however, the height of the thick albumen (side view) is the most important factor in determining grade of an egg (figure 4). When a stale (old) egg is broken out, the yolk is flattened and often displaced to one side and the surrounding thick albumen has become thinner, resulting in a large area of albumen collapsed and flattened to produce a wide arc of liquid [3].

![Figure 4: Grades of broken eggs by broken-out method](image)

Source: [36]

On the base of quality edible eggs are divided in to three grades. Grading aids orderly marketing by reducing waste, confusion and uncertainty with respect to quality values. Once graders acquire a working knowledge of the standard of an egg quality, accuracy in interpreting quality standards and ability to correct grade classification will increase. Based on the criterion as shown in Table 1.
Table 1: The criteria that used to grade eggs based on internal and external parameters

<table>
<thead>
<tr>
<th>Factors</th>
<th>Grades</th>
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<tbody>
<tr>
<td></td>
<td>AA</td>
</tr>
<tr>
<td>1. Shell:</td>
<td></td>
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<tr>
<td>-Outer shell</td>
<td>-Free from check</td>
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<tr>
<td></td>
<td>-Smooth surface,</td>
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<td></td>
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<tr>
<td>2. Candling</td>
<td></td>
</tr>
<tr>
<td>2.1 shell</td>
<td>-Clean and free from inner cracks</td>
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<td></td>
<td></td>
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<tr>
<td>2.2 Air cell</td>
<td>-1/8 inch or less in Depth</td>
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<tr>
<td>2.3 Albumen</td>
<td>-Clear Firm</td>
</tr>
<tr>
<td>2.4 Egg Yolk</td>
<td>-Outline slightly defined</td>
</tr>
<tr>
<td>3. Break-out egg</td>
<td>-Round and bulging shape located in the middle of the thick albumen</td>
</tr>
<tr>
<td>3.1 Egg yolk</td>
<td></td>
</tr>
<tr>
<td>3.2 Egg white</td>
<td>-The thick white is firm and round.</td>
</tr>
</tbody>
</table>

Source: [39].

Zoonotic Importance of Poor Quality Egg:

Health issue associated with eggs is contamination by pathogenic bacteria, such as salmonella enteritis. Salmonella spp is a group of organisms that are closely related to one another and probable should be considered as a single species. Salmonella spp infections appear to be one of the most typical examples of an enteric disease which can transmit to human via consuming raw eggs. More than 2,000 serovars of Salmonella spp have been described, and all are considered to be potentially pathogenic for animals, including humans. Salmonellosis in humans can produce symptoms ranging in severity from intestinal disturbances to death. It is characterized by diarrhea, fever, abdominal pain or cramps, vomiting and headache. The incubation period ranges from 8 to 72 hours [40]. Even though the original population of S. enteritis in liquid egg seems to be low, there is potential for these populations to increase to levels capable of causing disease. Temperature abuse of the egg product can lead to higher numbers of organisms that may not be completely eliminated by current pasteurization protocols [41]. A bacterium, Salmonella Typhim can be inside perfectly normal-appearing eggs, and if the eggs are eaten raw or undercooked, the bacterium can cause illness. However, the nutrients that make eggs high-quality foods for humans are also a good growth medium for bacteria. For this Vulnerable groups such as pregnant women, the elderly and babies are additionally advised to consume only eggs where the yolk and white have been cooked until they are solid [42]. Egg quality is an important criterion for egg producer and has important in economic implications. Poor egg quality is a serious problem in egg industry and at least 10-15 percent of all egg are rejected. Egg physical quality which refer
to egg shell cleanliness, thickness, shape and integrity directly impact farmer income via downgrading rate.

Conclusion and Recommendations

The quality of an egg is defined by its internal and external attributes of eggs which are determined by candling and broken-out methods. Egg can be classified into three main grades; namely, AA, A and B based interior and exterior quality of an egg. Many factors like management, nutrition, genetics, age of the hen, temperature, disease and housing have a significant impact on the quality of egg reaching the consumer. The effect of these factors on the internal and external parameters of an egg can be down grade the quality of eggs. In developed countries eggs are graded before providing to market. However, such practices are not followed in developing countries like Ethiopia and also no more researches have been conducted on quality determination, grading and affecting factors.

Based on the above conclusion the following recommendations are forwarded:

- Effective and efficient management should be given for both egg and hen to get high quality product.
- In order to optimize egg quality by egg producer, the influential factors should be identified and solved.
- Different researches should be conducted on egg quality determination and grading system in Ethiopia
- Care must be given to prevent the egg shell from contaminated with fecal matter in order to reduce zoonotic disease

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