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External and Internal Conditions Affecting Fertilization and Hatching of Avian Eggs

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Abstract

Consumer acceptance of table and hatching eggs is largely determined by the qualitative features of eggs, including their exterior and interior properties. It also has a significant impact on the technology used to produce egg products, including powdered, frozen, and liquid eggs. Egg weight, freshness, eggshell integrity, and cleanliness are among the exterior qualities. Whereas an egg's interior characteristics include its chemical makeup, yolk index, Haugh unit, and other factors. Extrinsic and intrinsic features are related to housing, storage, stocking density, nutrition, housing conditions, the handling of eggs, and the stage of the production cycle. These egg properties can also be strongly impacted by shelf life.

Keywords: Characteristics; External; Internal; Weight; Shape; Shell

Introduction

Hatchability, fertility, number of eggs laid, and quality attributes of the eggs are often factors that affect the productivity and profitability of poultry species [80,8]. However, a number of other variables, including body weight, breed, strain, season, rearing techniques, and relative humidity, can also have an impact on egg quality [45,36,55,48,66,78,47,87,89,39]. Also, scientists have noted that a number of egg characteristics have a genetic basis and depend on the genetic diversity of females, which is primarily accountable for the ability of fertilized eggs to hatch [79,85,3,86,88]. The genetic quality of eggs can be improved by comprehending genetic heterogeneity [69].

Main Text

External egg characteristics:

i. Egg weight:

The egg of a bird serves as both a means of reproduction and an important source of food for humans. Many bird species have different egg sizes and shapes. Both table eggs and hatching eggs need to be of a certain size and exterior quality. Egg weight affects both the nutritional content of eggs and the weight of day-old chicks [58]. A laying hen's egg weight is influenced by a variety of variables, including inheritance [19], breed, age, body size, feed and water consumption, environmental temperature, and disease [24,4,5,6]. Egg weight has a significant impact on egg quality and classification [23]. Without cracking any eggs, it is possible to figure out this parameter [3]. Protein, yolk, and shell make up a direct proportion of an egg's mass. Significant variability in egg size between white leghorn lines was documented by Marion et al. larger eggs often have a higher yolk-to-protein ratio, but light-colored eggs have a lower protein-to-yolk ratio [34]. Moreover, the egg's weight has an impact on the shell's quality. Compared to little eggs, large eggs have more cracks [3]. It has been found that there is a correlation between egg weight and the percentage of cracked eggs [1]. The importance of the relative proportion of egg components has significantly increased with the development of the egg-breaking industry [2]. The albumen and yolk, which are used for distinct markets and have

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different commercial values, are separated using thinners. The attribute of the egg that is most frequently connected to the durability of the shell is its weight. Shell thickness and egg size are tightly connected [27]. The size of the egg grows larger as the hen ages, while the hardness of the shell weakens [57,12]. There is a substantial correlation between egg mass and protein height (-0.021) and between egg mass and Haugh units, according to studies by Iposu et al. and Silversides (-0.198).

Ekeroglu et al. found similar findings, citing substantial correlation coefficients between weight and shape index (0.227), shell strength (-0.207), yolk width (0.759), yolk height (0.589), yolk color (-0.461), yolk index (-0.177), and protein index (0.345). Japanese quail eggs ranged in mass from 8.31 to 13.00 g. The weight categories of quail eggs affected the fertility percentage considerably ($P < 0.001$); the greatest value was 91.06% with the heaviest group > 13.00 g. The hatchery sector also greatly benefits from the optimization of egg storage times and conditions [11,82,83,84]. Around the midpoint of the production phase, Iqbal et al. discovered a significant difference ($P \leq 0.05$) in the weight loss of the eggs in groups of various sizes. They continued by saying that there was no discernible difference between the tiny and medium-sized egg groups and that the big egg size group experienced the least amount of weight loss over the course of various incubation intervals, with losses ranging from 3.27% to 11.32%. The ideal holding time for quail eggs prior to incubation is neither documented nor advised [74]. According to Egbeyale et al. varied storage periods had an impact on the weight loss of laying hen eggs during incubation, which decreased as the storage period before incubation rose.

While a sizable body of literature has been devoted to studying the intrinsic and extrinsic characteristics of eggs, less study has concentrated on the common elements that can affect both aspects. The weight or size of the egg is probably one of the primary components, along with other aspects, that can alter or shape both features in poultry [50]. It is widely acknowledged that egg size impacts incubation success, embryonic mortality, and hatchability. Egg size also affects eggshell qualities and the exterior quality of the egg [62]. At the very beginning of life, thyroid hormones are crucial for the healthy development of nearly all bodily structures in the embryo. The most significant endocrine regulators of the development of embryonic muscle, the process of hatching, and post-hatch metabolism, for instance, are thyroid hormones [72]. As pulmonary breathing starts in an embryo at a late stage, plasma T3 levels rise noticeably [15], and fetal thyroid hormone levels rise along with an improvement in embryonic survival rates. To our knowledge, no research has been done on the connection between egg weight and fetal thyroid hormone levels. On day 6, thyroid hormone levels did not significantly differ across egg groups; however, on day 14 ($p \leq 0.05$), there was a significant difference [29] (Figure 1).

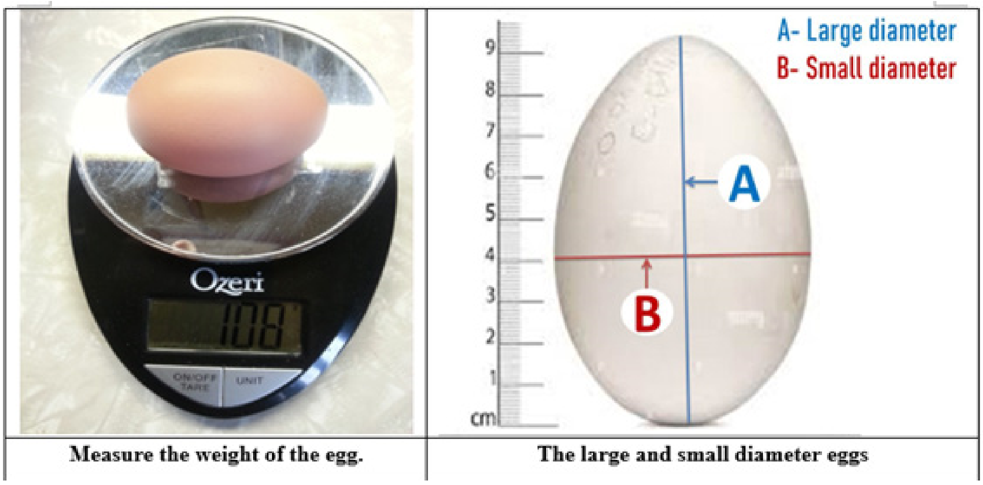


Figure 1:

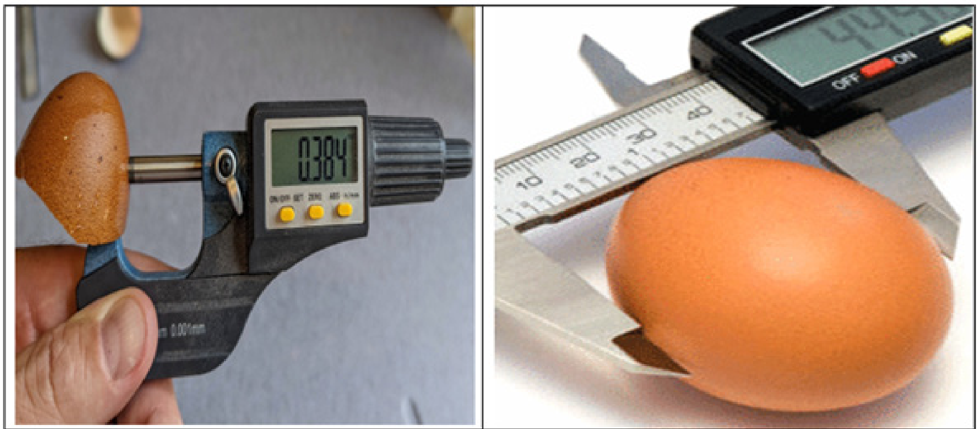
ii. Egg shape:

In addition to the specific gravity, mass, volume, surface area, and percentage of the eggshell, its strength is influenced by its microstructure, thickness, and loading rate. In recent years, some academics have become interested in one of these elements: the morphology of laying eggs [46]. An essential factor in identifying the quality of the egg is the egg shape index, which is calculated as the width-to-length ratio of the egg. Domestic chickens typically lay oval-shaped eggs; therefore, eggs that are strangely shaped, such as long and narrow, spherical, or flat-sided, cannot be categorized as AA (nearly ideal) or A (slightly lower than AA) [72-76]. Eggs that are round or exceptionally long do not look good and do not fit well in egg cartons; as a result, they are significantly more likely to break during transit than eggs that are of a typical shape [59]. A positive link exists between the egg shape index and protein quality [16]. The study found definite relationships between the form index and a variety of variables, including egg white length, yolk breadth, height, and color [61]. Also, a lot of researchers have found a link between egg length or width and form index [16]. Nevertheless, a substantial inverse relationship between egg shape index and shell thickness was discovered by Alkan et al. in.

iii. Egg shell:

The eggshell shields the embryo from physical harm and microbial contamination, controls the exchange of water and gases between the embryo and its surroundings, and serves as a calcium source for the growing embryo [68]. Eggshell quality can be influenced by a variety of parameters, but the most crucial ones are bird genotype, usage type, rearing technique, environmental circumstances, and mineral feed additions [73]. The main purposes of the eggshell are to protect and provide calcium and other minerals to the embryos as well as to ensure gas and water exchange between the embryos and the outside environment, which is essential for the success of the entire incubation and hatching process [51]. Particularly, gas exchange takes place by diffusion through small holes on the eggshell's surface [54], and as a result, it is dependent on the quantity of pores and the thickness of the eggshell [52]. Both features alter the proportion of egg weight loss (EWL%) during incubation, which has an impact on the eggshell's ability to exchange water. Gas exchange is hampered by an increase in eggshell thickness and a decrease in the number of pores, which ultimately results in embryonic death [67].

Eggs gain weight while generally losing thickness and strength during the manufacturing phase. The size and weight of the egg affect the eggshell's quality. Strong correlations were found between the shell's strength and thickness. The percentage of change in crushing strength is significantly influenced by the form index [10]. The handling of the egg after laying is particularly crucial since egg parameters like form index and shell thickness influence the likelihood of fractured eggs. Eggshell strength and integrity are crucial during storage and incubation to prevent water loss, microbial entry, and premature gas diffusion before incubation [18]. The viability of the embryo during egg storage is significantly impacted by the integrity of the eggshell, in addition to the durability of the interior components. Modifications to the egg's physical properties, such as its protein pH, can induce nutrients to diffuse from the protein to the blastoderm and decrease the egg's resistance to gaseous diffusion. This results in necrosis and regressive changes in the blastoderm, which hinder the embryo's ability to develop [Egbeyale et al.] As a result, great care should be taken to ensure that eggs are of the best possible internal and external quality for storage and incubation (Figure 2).



Measurement of the eggshell	Measure the small diameter of the egg.

Figure 2:

The total pore number, surface area, eggshell volume, and eggshell mass of large eggs were all considerably higher than those of small eggs in terms of eggshell quality metrics ($p < 0.05$), followed by a higher hatch rate and hatch mass. Egg weight and several exterior and internal measures of egg quality showed substantial relationships ($p < 0.05$) according to Pearson's correlation coefficients [29]. The development and hatchability of chicken embryos can be impacted by the shell's properties. The shell is a source of the building blocks required for the embryo's healthy development because the egg is a closed system with regard to the minerals present [49]. A putative positive association between the processes of shell pigmentation and its calcification has been demonstrated to exist between the intensity of shell pigmentation, its thickness, and the hatchability of chickens [31]. Better hatchability may come from this, since it has been demonstrated that thicker-shelled eggs can produce hatch results that are up to 9% better than those of thinner-shelled eggs [13]. Japanese quail eggs' "blue" or speckled shells do not seem to impact their quality if used for human food. However, the hatching success and live weight of the ensuing Japanese quail chicks might be altered by the color of the eggshell [20].

iv. Storage period of eggs:

Procedures for incubation are crucial for sustaining and enhancing quail egg production. In the production of broilers, the eggs are typically gathered for a period of 1 day to 3 weeks prior to incubation in order to obtain enough eggs to fill the incubator [38]. Eggs must be kept at low temperatures during storage to stop embryonic development. Eggs should be kept at a room temperature of 20 to 25 °C for storage times under four days, 16 to 17 °C for storage times between four and seven days, and 10 to 12 °C for storage times exceeding seven days [42]. The eggs evaporate water during storage; the rate of evaporation is influenced by temperature and relative humidity. According to studies [56, 11], the quality of hatching eggs and table eggs is negatively impacted by long-term storage. It is usual for eggs from broilers and turkeys to lose 12 to 14% of their water during incubation [53]. The likelihood of non-hatching increases as the number of storage days increases because more embryos die while being stored and incubated [56]. After seven days of storage, some researchers have noted hatchability declines of up to 5% per day [41]. In hens, it has been suggested that a storage duration of 10 days is appropriate to retain higher egg quality, a better Haugh unit, and lower the rate of unfavorable physicochemical changes in the egg [81]. According to the findings, the hatchability of eggs in meat and egg-type quails was approximately 84% up to 10 days of storage before it sharply declined [56].

Moreover, changes in protein quality that are time-related and potentially impact the hatchability of eggs are strongly correlated with storage temperature [14]. According to Goodrum et al., when eggs were held at high temperatures, protein pH quickly increased. Early embryonic mortality is influenced most by albumin quality [14]. According to Van Schalkwik et al. storage temperature plays a significant role in influencing the viability of the embryo. Quail eggs must be stored at a lower temperature in order to increase hatchability. If adapted, a cold clay pot can serve as an alternative to buying a refrigerator and be the best option for places without electricity in the country [7].

The following formulas were used to determine the external and qualitative characteristics of eggs:

Weight loss (g) = Initial weight – final weight

Weight loss (%) = Weight loss (g)

Initial weight (g)

Shape index (%) = [Egg width (mm) / Egg length (mm)] x 100

Shell ratio (%) = (Shell weight(g) / Egg weight(g)) x 100

Egg weight (g): The eggs were weighed separately.

Shell weight (g): After the eggs were broken, the eggshells were washed with water and dried to remove any remaining protein. Following this procedure, the weight of the shell (with membrane) was measured.

Shell thickness (mm): Shell thickness (with membrane) was measured at the sharp poles, blunt poles, and the equatorial portion of each egg. The average shell thickness was obtained from the averages of these three parts.

Surface area (S) was calculated using the formula $S=4\pi r^2$. The radius (r) was calculated as ¼ (length + width) of the egg.

The thickness of four shell pieces, one at both ends (wide end and narrow end) and two from the body of the egg, was measured to the nearest 0.01 mm using a helical grid and averaged.

Egg surface área (ESA, cm^2) = 3.9782 x $EW^{0.75056}$

Where EW is the egg weight (g)

Unit surface Shell weight (U, mg)=SW

Cm^2 ESA

Where

SW= Shell weight (mg)

ESA= Egg surface área (cm^2)

Hatchability %=Number of hatched chick x 100

Number of set eggs

For the subsequent determination of the indicator "weight and volume ratio", a comparative analysis of the distribution of eggs was carried out according to the theoretically calculated indicator "egg volume".

N 1: $V=((\pi LB^2/6) - 0,022(\pi LB^2/6))/1000;$

N 2: $V = (0.6057 - 0.0018 * d) * D * d * d / 1000;$

N 3: $V=0.523*D*d*d/1000;$

The actual egg volume (Vf) was determined by the formula: Vf = M1–M2,

where M1 is the mass of the egg in air and M2 is the mass of the egg in distilled water. The data on the calculation of the actual value of the density of eggs and the theoretically calculated values of the ratio of mass to volume are given.

v. Internal egg characteristics:

The egg's functional qualities are correlated with its interior quality. The internal quality of an egg has been measured using a variety of techniques, but the impact of temperature has not been completely investigated. Sometimes the temperature is not stated or is stated as a range, such as room temperature [35,37]. This may have an impact on the findings and make it challenging to compare studies. The accepted method for assessing an egg's interior quality uses Haugh units (HU). HU, a non-linear function, measures the rate of quality loss [28]. The reliability of Haugh's approach and its correction for egg weight have been contested by a number of researchers. For instance, Eisen et al. observed a bias in the HU regression when they compared direct measurements of albumin height with HU calculations. According to their findings, protein height was overestimated in smaller eggs and underestimated in larger eggs when egg weight was taken into account. Wesley and Stadelman discovered that HU correlates well with the appearance of broken eggs and correlates strongly with other quality measures, such as thin white diameter, yolk centering, thin white shape, thick white shape, percentage of outer thin protein, percentage of thick protein, and percentage of total liquid protein. However, the validity of their findings has been questioned. According to Silversides et al. the HU technique does not need to account for egg weight when gauging the freshness of eggs at room temperature. Additionally, they contend that it was incorrect to compare HUs from various herds. They suggested gauging the protein's height to assess the eggs' quality.

Wilgus and Van Wagenen contrasted the height of a fat squirrel with the height of a fat squirrel adjusted for egg weight while creating methods for assessing squirrel height. They discovered that the r2s were the same and that it was simpler to determine protein height without correction. The variety and age of the hen have been proven to affect albumin height in recent research by Silversides and Scott (Figure 3).

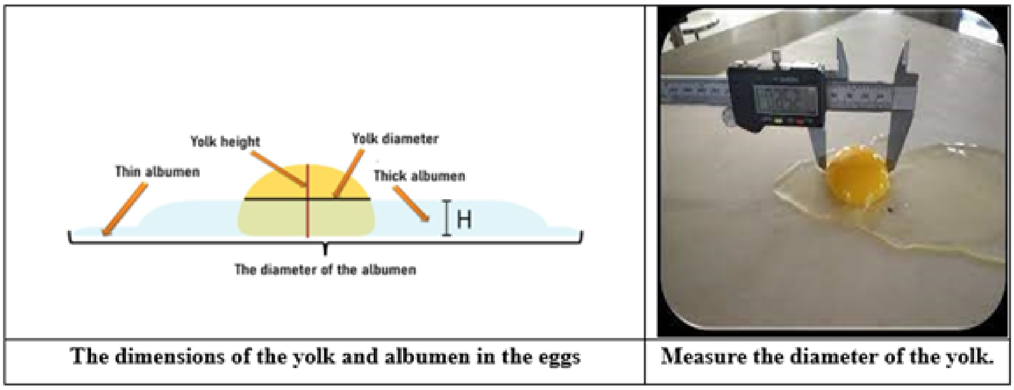


Figure 3:

While egg weight has no bearing on the protein index, Heiman and Carver found that the albumen index—as computed in the Materials and Methods section—was superior to other quality indicators. Sauter et al. discovered that the albumen index was strongly linked with the quality loss indicated by candling. The albumen index's quality loss rate is a non-linear function, much like HU, which is one of its main drawbacks.

For the sake of food safety, the robustness of the yolk membrane is becoming more and more crucial [44]. With rising egg age, the yolk membrane's strength declines. This might enable any microbes in the white to access the nutrients in the yolk. Membrane strength levels are substantially correlated with the yolk index and HU, according to Kirunda and McKee's research.

According to Wesley and Stadelman [1959], the yolk index was not as accurate even though it was connected with other internal quality indicators like the percentage of external thin protein, the percentage of thick protein, and the total percentage of thin protein. It provides a thorough picture of the overall quality of the eggs, much like HU. These findings concurred with those of Sharpe and Powell, who discovered that during storage, the height of the thick protein layer drops more quickly than the yolk index. The impact of elements like egg testing temperature and age on these quality indicators has received less study. According to Spencer et al. the interval between a breakthrough and a measurement can have an impact on quality metrics. HU and albumen height measurements of albumen quality revealed a linear deterioration with the logarithm of time since the breakthrough. Also, the age of the egg and the breed of laying hens both had an impact on the rate of loss. A linear drop of -1.15 HU with a 10°C increase in test temperature was noted by Stadelman et al. in (Figure 4).

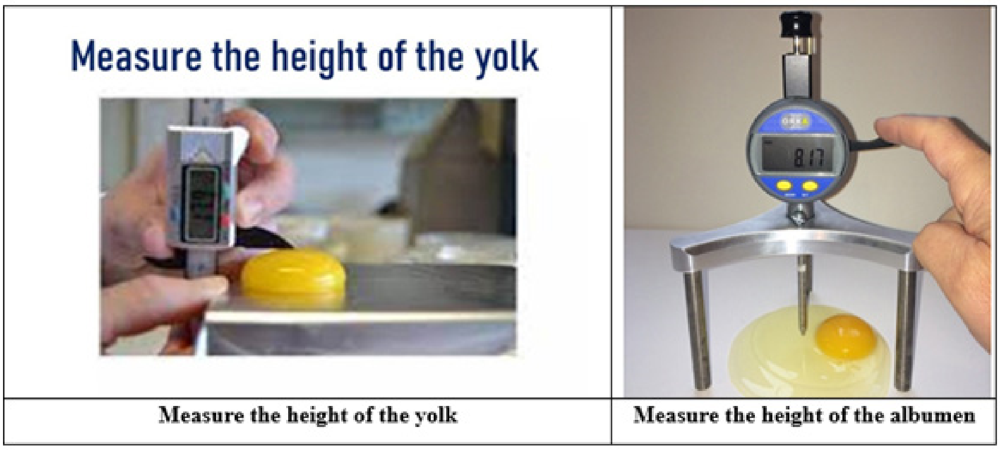


Figure 4:

To determine the internal quality characteristics of eggs, the following formulas were used:

Albumen weight (g) = Egg weight – (Shell weight + Yolk weight).

Yolk ratio (%) = (Yolk weight(g) / Egg weight(g)) x 100

Albumen ratio (%) = (Albumen weight(g) / Egg weight(g)) x 100

Yolk/albumen ratio (%): Yolk was weighed after being separated from the broken eggs.

Albumen index (%) = [Albumen height(mm)/{(Albumen length(mm) + Albumen width(mm)) /2}] x 100

Haugh unit = 100 log [Albumen height (mm) + 7.57 – 1.7 x Egg weight(g) $^{0.37}$]

Conclusion

Many factors can affect the external and interior egg quality characteristics, as was previously demonstrated. It is possible for the egg producer to regulate eggs and improve egg quality by being aware of this variety of elements. The quality of the finished product is influenced by good poultry management, best practices, and the careful gathering, handling, and processing of eggs.

Acknowledgment

None.

Conflict of Interest

None.

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