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NON-GENETIC FACTORS INFLUENCING INTERNAL EGG QUALITY TRAITS IN CHICKEN: A REVIEW

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ABSTRACT

Poultry eggs are used as breakfast meals in every corner of the world due to its easy availability and affordability; majorly being a rich source of protein. The nutritional component of an egg is purely determined by internal egg quality (albumen and yolk). This review paper thus focuses on the non-genetic factors affecting the internal egg quality characters of table eggs. The aim of this review paper is to address and improve the internal egg quality ensuring good quality albumen. Different journals were searched and studied on related topics before starting the review. The journals were selected from different parts of the world randomly visualizing the overall condition of poultry eggs and their internal egg quality characters. Haugh unit is regarded as the standard measurement of the albumen quality while color characteristics of yolk are regarded as the measurement standards. The protein content of albumen is mainly affected by the age of hens; the impact of different diseases and storage duration and conditions (temperature and humidity). Increasing the age of hens results in a lowering of the albumen index and albumen quality along with the lowering of egg production. Carotene content in feed ingredients gives better yolk color and yolk characteristics; high lysine and ascorbic acid resulting in better albumen quality to some extent. Vitamin A supplementation along with feed has shown a somewhat decreased incidence of blood and meat spots. The Haugh Units significantly decrease with the storage period but this declining quality can be minimized by maintaining low-temperature storage conditions up to 7-10 days. Eggs are a rich source of protein consumed in daily life in every household. Eggs are selected by visualizing the external eggshell quality but the internal albumen quality is very important because the protein content solely depends upon albumen. Thus the researches should be conducted for improving the internal egg quality characters.

KEY WORDS

Chicken eggs, Haugh units, albumen, yolk, egg structure.

Livestock has been contributing indispensable role in human nutrition and agriculture since a long time ago. According to FAO (2019), in developed countries around 40 percent of total agricultural outputs come from livestock sector supporting at least 1.3 billion people throughout the world. Poultry, being a component of livestock production with dual meat and egg purpose is an inseparable part of both subsistence and commercial farming in this sector. Production of eggs in 2018 was recorded 76.7 million metric tons increased by over 100 percent since 1990; China being the top producer since past three decades (Shahbandeh, 2020). Egg production; thus has significant role in development of poultry and livestock sector overall which is highly affected by egg quality traits. The egg production quality traits are affected by genetic and non- genetic factors of a laying hen. Mohan et al. (2018) reported that genetic factors can be improved by the artificial insemination in commercial production for chicken rearing while they are neglected or not much considered in subsistence farming.

This review article will be focused on the internal egg quality traits of table eggs; not on the eggs for rearing purpose. The non- genetic factors can be highly improved by the farm owners which have been proved for better egg quality traits of laying hens. Strain, nutrition and water, housing systems of poultry, Storage and freshness of eggs, stress, and health condition have much impact to determine internal egg quality. The internal egg condition determines the egg quality. Egg yolk or yellow part (30-33%); albumen or white part (around

60%) and egg shell (9-12%) is the composition of a healthy egg (Roberts, 2004) similar as reported by Stadelman et al. (1990).

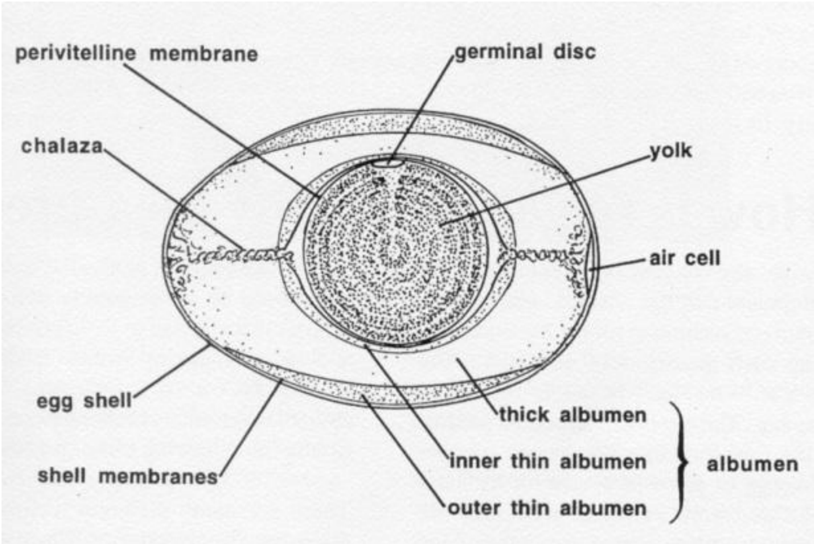

Figure 1 – Internal Structure of Egg (Source: Poultry Hub)

Internal egg quality depends upon the albumen quality, yolk quality, existence of blood or meat spot and air cell size (Ketelaere et al., 2004). The main objective of this review article is to study and analyze the elements that affect the yolk and albumen quality of the poultry eggs.

Haugh (1937) introduced an evaluation technique of the albumen quality which is most widely used as internal egg quality measurement techniques so far. According to Haugh, the formula to calculate Haugh Unit is:

$$HU=100.\log\left[H-\frac{\sqrt{G}(30W^{0.37}-100)}{100}) + 1.9\right] \quad (1)$$

Where: HU= Haugh Units; H= Height of albumen (in mm); G= Gravitational constant; W= Weight of egg (in gm).

This formula was further simplified as:

$$HU= 100.\log\left[H-1.7W^{0.37}+7.57\right] \quad (2)$$

On the basis of Haugh Unit score, Jones et al. (2012) classified eggs as AA (100-72 HU); A (71-60 HU); B(59-30 HU) and C(less than 29 HU) also stated by De Menezes et al. (2012).

Candling is a non- destructive method of quality identification of internal portions of egg. A dark room with plain homemade device or mechanical appliances can be used. The modern devices can categorize up to 120000 eggs per hour (Ketelaere et al., 2004). This process has an advantage of labeling eggs without destruction but is less reliable and time-consuming. In the candling process, white beam of light is passed through the egg, resulting the shadow that indicates the exact location and condition of internal parts of an egg (Ramzan, 2019). Computer vision techniques are also used to observe blood spots. Neural network detection along with color image analysis can be used to examine blood spots with 92.8% accuracy (Patel et al., 1998).

Schimilovitch et al. (2002) were able to estimate pH of the whole egg from IR ray detection which was also supported by Kemps et al. (2006); also for the prediction of estimating both pH and HU by IR detection (Bamelis et al., 2006). Brant et al. (1953) chose 577nm to detect blood spot but later on Gielen et al. (1979) provided the range of 585-610 nm to observe the blood value of an egg.

A research conducted in Rhode Island Red* Sussex light hens of two age groups 30-40 weeks and 150-200 weeks divided into layers and non- layers; the rates of egg production were 66-77% in the older age group category while over 90% in the younger age group of layer hens. The research also concluded that old age group hens produced large sized eggs compared to the younger hens but with high cracking incidence of egg shells (Joyner et al., 1986). The eggs of hens with Vanaraja male line (PD1) of various age groups of 28, 40, 52, 64 and 72 weeks of age; yolk color were significantly different with more intense color at 64 week hens' eggs. Poor albumen index, decreased albumen height, increased albumen width, increased yolk percentage with increasing age of hens but not significant difference observed in yolk index. Both albumen and yolk weight also increased with the growing age but did not show constant difference with growing age (Padhi et al., 2013). But, Fletcher et al. (1982) reported no significant relationship of hen's age with yolk solid content and the only way to increase yolk content is to increase the size of the yolk; experiment conducted in a commercial strain Shaver in South Georgia. Unlike this; the increasing age of hen has less total albumen content resulting the lesser solid albumen. According to an experiment conducted in Warsaw University of Life Sciences in Poland, albumen height and Haugh units was highest in younger hens of 25- 26 weeks of age by 22% but yolk weight and yolk ratio was higher in eggs laid by older hens (experiment conducted among 25-26, 45-46, 55-56, 69-70 weeks old hens) (Marzec et al., 2018). The yolk index decreased from 45.31-39.78 and from 41.32-30.92 at temperature 200C for eggs collected from 22 and 40 weeks aged hens during 14 days of storage (Akyurek & Okur, 2009).

In a research conducted in Egypt with the four levels of DDGS (distillers dried grains with solubles- 0%, 6%, 12% and 18%) and two levels of EEM (exogenous enzyme mixture- 0 and 250 gm. /kg of diet) in 144 Hisex brown laying hens; feeding of 6% of DDGS resulted lowest albumen and highest yolk percentage in egg (Mohamed et al., 2019). The research also reported higher the DDGS content in feed more is the albumen and yolk percentage but it also increases the cholesterol and pigmentation levels of yolk while the feed intake and egg production was highest with 6% DDGS level (116.54 gm./day and 93.77% respectively); feed conversion highest with 18% DDGS level (1.93 gm. feed/ gm. egg). The comparative research of fermentation metabolite product and standard layer rations conducted by Martinez et.al. (2018) concluded that the addition of fermentation metabolite product @1.25 gm./ kg in feed of the laying hens increased the albumen nitrogen and yolk quantity but with less nitrogen content in yolk; high feed consumption and feed conversion rates but no significant difference in egg production. Yolk color is highly affected by diets which might reduce significantly by 4-5%, 7-11% and 3-6% if rice pollard, triticale and barley are added as the feed ingredients respectively (Karunajeewa et al., 1978). A review article by Roberts (2004) suggested increased lysine and ascorbic acid in diet gives higher albumen content in poultry eggs but with high neem kernels and crude oil reduce the Haugh Units. Addition of 10% alfa- alfa (Sauter et al., 1952); addition of vitamin A (Bearse et al., 1953); not using trichloroethylene extracted soybean meal (Hill et.al., 1956) and green grass fed hens (or free ranged hens in green ground) (Nalbandov et.al., 1944) can reduce the appearance of blood or meat spots to some extent though this defect is mainly governed by genetic factor (Rhode Island Red more susceptible than White Leghorns) (Sherwood, 1958).

In an experiment conducted with 600 hens in 8''*18'' and 400 hens in 10''*18'' cages of same breed White Leghorn in an intensive rearing system; the appearance of body checks was almost double in 8''*18'' compared to 10''*18'' cage system although no internal quality of eggs are mentioned (Dorminey et al., 1964). A research conducted with four variations storage temperature (25^0 C and 8^0 C), storage time (7, 14 and 21 days), age of hens (35, 40, 45 and 50 weeks) and housing densities (357.14, 416.6, 500 and 625 cm^2 per bird) by (De Menezes et al., 2012) concluded that the best mean values of Haugh units was found with the eggs produced by the hens with biggest housing space i.e. 625cm^2/ bird. There was only one exception of having better albumen height in 500 cm2/ bird density than 650 cm^2/ bird in 7 days of storage time with temperature 8^0 C. The variation in results might be due to multiple variables taken with average in age of hens. The albumen quality for eggs of brown layers decreased significantly by 2.23 HU in conventional than organic rearing system but the albumen quality was not significantly changed for white layers in both rearing systems (Kamil et al., 2012). The yolk color score (yellowness of yolk) was higher in conventional system than in organic system for both white and brown layers. This might be due to no available grass during summer; or high carotenoids composition in conventional feed or also might be due to the carotenoids acting as a protective measure from solar irradiation for organic system birds rather being used as yolk color. The albumen index and Haugh Units were higher in eggs laid by birds in cage system than litter system in case of Hybrid Lohmann Brown- Classic (Kraus et al., 2019) whose results also matches with the conclusion reported by Vlčková et.al. (2014).

Heat stress with high ambient temperature reduced feed intake by 20% in hot season in North Guinea Savannah (Ayo et al., 2011).Under two treatment temperatures (26^0 C as comfort and 35^0 C as thermal stresses) for the two strains Hy- line W36 and Hy- line brown; the Haugh units were significantly different. There were the differences by 2.8 HU and 3.2 HU (in W36 and brown strains respectively) raised in litter system under thermal stress (Barbosa et al., 2005). According to Illuminating Engineering Society of North America (IESNA); 14 hours of photoperiod and minimum of 10 lux of light intensity within the visible range of 664-740 nm is suitable for the egg production. The photoperiod higher than 17 hours and light intensity higher than 10 lux might cause the negative effects (aggression, cannibalism, hyperactivity, etc.) but surely won't enhance egg production. A literature review by Jácome et al. (2014) has also pointed that artificial lighting influences the egg production but not the egg quality traits. But; the lighting directly influences the feeding behavior of the laying hens which also affects the internal egg quality traits. Though much research has not been done in lighting; light stress can also affect the internal egg quality traits (both qualitative and quantitative) indirectly. According to a research conducted in Brazil for comparing the efficiency of two lighting systems (linear LED strip lighting system and conventional LED bulb lighting); all the eggs produced by hens had albumen quality higher than 90 HU which is the best quality grade according to USDA; but linear LED strip lighting system was observed to be better than conventional LED bulb lighting system (Juliana et al., 2019).

The effects of storage period were remarkable in nearly all internal egg quality traits (Khatun et al., 2016). According to De Menezes et al. (2012), research conducted on Dekalb White hens in Brazil, higher the storage period, the internal quality of egg degrades, regardless of temperature. The research also suggested the eggs under refrigeration had better quality than the eggs stored at room temperature similar as the results stated by Campos & Baiao (1975) and Santos et al. (2009). The albumen height was markedly decreased from 8.5mm to 2mm at 250C temperature in 30 days of storage (Min Hee Lee et al., 2016). The same research stated that HU also significantly decreased from 87.62 to 60.92 in the span of 10 days of storage. On the basis of a research conducted in Saudi Arabia among two colored shell eggs (white and brown); storage period had a significant effect upon Haugh units and appearance of blood spots while heredity had only effect on appearance of blood spots; while both the storage period and heredity had no effects on yolk color (Alsobayel & Albadry, 2010). This clearly shows that the yolk color is mainly affected by the composition of feed ingredients rather than storage. The HU of egg declined from 91.48 to 52.11 at 20^0 C within 14 days laid by hen of 22 weeks age; while 81.53 to 32.55 HU at constant temperature and storage time for 50 week aged hen (Akyurek & Okur, 2009).The same research paper insisted that there was no change in both internal and external weights of the eggs with the storage period which was also reported by (Ahn et al., 1997). The carbon dioxide content loses gradually with the storage period increasing the alkalinity of the egg leading to the deterioration of albumen quality by liquefaction (Williams, 1992).

An air space present in an egg increases with the storage time due to evaporation of the inner water content of the egg (Williams, 1992). This evaporation of the inner water content causes the degradation of the inner quality traits. Temperature and humidity are mainly responsible for evaporation. Loss by evaporation is the linear function of difference in relative humidity of outside and inside portions of egg (Romanoff et al., 1949). Carter (1968) recommended the relative humidity of 80-85% and temperature of $(0- 0.5)^0$ C for storage but

Williams (1992) suggested the temperature below 10^0 C for storage due to difficulty of refrigeration and to avoid risks for condensation of eggs. There was also significant increase in pH of both albumen and yolk at 20^0 C than 5^0 C (Akyurek & Okur, 2009). The internal protein structures start breaking down if the internal temperature goes above 7^0 C (Okeudo et al., 2011) also stated by Farhad et al., 2011).In 30 days of storage time, the initial albumen quality of 91 HU deteriorated to 84.6, 70.7 and 32 at temperatures 2^0 C, 12^0 C and 25^0 C respectively (Min Hee Lee et al., 2016).

The mean egg weight was found to be decreased by 6.4 gm. when compared to the eggs laid by healthy hens and hens affected by infected bronchitis (HV1/9) affecting almost all internal egg quality traits (Butler et al., 1972). The degradation of protein quality and quantity was also mentioned due to decline in ovomucin and lysozyme which are the major components of thick albumen. According to the same research, infectious bronchitis caused the lesions in albumen secreting tissues (observed by histological examination) in the oviduct and reduction in glycoprotein content which is responsible for secreting ovomucin giving the watery appearance of albumen. The major diseases in poultry like infectious bronchitis, influenza, Newcastle disease, etc. has shown remarkable effects in number of egg production in poultry with the degradation of egg weight although not much research has been conducted in internal egg quality traits (Roberts, 2014). The review paper stated that egg production has been reported to decrease from 10-40% with thin, soft and decreasing shell pigments in the hens infected by Egg Drop Syndrome.

Conclusion. Among non- genetic factors affecting internal egg quality; age of hens has the most important role determining albumen quality in fresh laid eggs. Younger hens lay eggs with good albumen quality than aged hens although an induced pause can also lead better quality albumen in aged hens. The diseased layers especially with infectious bronchitis lay significantly lower quality albumen than healthy layers. The watery albumen with very low solid albumen content is the peculiar characteristic of the eggs laid by diseased hens. Feed ingredients do not much affect the albumen quality but influences highly in yolk color. The temperature during raising of hens do not much affect the albumen quality although the storage temperature highly affects the albumen quality. Free range housing system has been proved for higher internal egg quality than intensive housing system although proper maintenance of proper composition of feeding ingredients and spacing does not affect much in internal quality of egg. Proper lighting in housing systems without any stress has been proved to lay the eggs with better internal quality traits.

Delay for transportation in haphazard storage conditions up to consumer's table has significant negative effects in both albumen and yolk quality characteristics. Appearance of blood and meat spots (mainly found to be as a genetic cause) might also appear if the storage period is extended. Higher the storage period, lower is the quality of albumen. For the higher storage period; maintenance of low temperature (0-10^0 C) and 80-90% RH has been proved to conserve internal egg quality to higher extent. Ensuring the prevention of diseases in hens, good storage conditions with proper feeding and lighting condition ensures better internal egg quality traits.

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