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Identification of The Lohman Brown Strain Purebred Chicken's Eggshells Based on Egg Age

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ABSTRACT

This study aimed to identify the shell quality of Lohman brown strains. A total of 460 eggs aged 1–14 days from Lohman brown strains were collected from community farms in Gowa, South Sulawesi, Indonesia. The study variables included egg weight, egg index, shell weight, thickness, and percentage. Analysis was conducted using analysis of variance (ANOVA), and the difference in shelf life was analyzed using Duncan's multiple range test. The results revealed that egg weight, egg index, shell weight, shell thickness, and shell percentage significantly ($P<0.05$) affected egg age from 1 to 14 days. The study concluded that older Lohman Brown strain chicken eggs have reduced weight and shell thickness. Additionally, egg age significantly impacts shell weight, but shell thickness decreases as the egg ages. The color classification of eggshells over 14 days, as indicated by hex codes and sRGB values, shows significant variation, with the darkest brown occurring on days 6 and 11 and the lightest brown on day 1.

ABSTRAK

Penelitian ini bertujuan untuk mengidentifikasi kualitas kulit telur strain Lohman Brown. Sebanyak 460 telur berusia 1–14 hari dikumpulkan dari peternakan masyarakat di Gowa, Sulawesi Selatan, Indonesia. Variabel penelitian meliputi berat telur, indeks telur, berat kulit, ketebalan, dan persentase. Analisis data menggunakan analisis varians (ANOVA), dan perbedaan masa simpan dianalisis menggunakan uji Duncan. Hasil penelitian menunjukkan bahwa berat telur, indeks telur, berat kulit, ketebalan kulit, dan persentase kulit secara signifikan ($P<0,05$) memengaruhi usia telur dari 1 hingga 14 hari. Studi ini menyimpulkan bahwa telur ayam strain Lohman Brown yang lebih tua memiliki berat dan ketebalan kulit yang berkurang. Selain itu, usia telur berdampak signifikan terhadap berat cangkang, tetapi ketebalan cangkang berkurang seiring bertambahnya usia telur. Klasifikasi warna cangkang telur selama 14 hari, sebagaimana ditunjukkan oleh kode heksadesimal dan nilai sRGB, menunjukkan variasi yang signifikan, dengan warna cokelat paling gelap terjadi pada hari ke-6 dan ke-11 dan warna cokelat paling terang pada hari ke-1.

Kata Kunci:
Kualitas kulit telur
Lohman Brown
Strain
Telur
Warna kulit telur

1. Introduction

The demand for chicken eggs in the last few years has increased along with the high demand for protein consumption in Indonesian society. The increasing demand for eggs is related to consumer perception of the egg's quality selection (Chang, Lahti, Tanaka, & Nickerson, 2018; Chen et al., 2023). One of the consumer perceptions is the color or brown of eggshells (Lusk, 2019). Consumer perception of the brown of eggshells affects the aspects of consumer acceptance, i.e. brown is preferable to over-spotted brown or pale brown. The kind of egg production is grown widely circulated in Indonesian society, namely imported hens of strain Lohman brown (Siddiqui, Toppi, & Syiffah, 2024). The Lohmann Brown strain type of laying hens is popular in the Indonesian commercial market, the strain is selection result from the Rhode Island Red types and was bred specifically to produce eggs (Toy et al., 2024). In one egg-laying cycle, the Lohman Brown strain usually can have around 170-200 eggs, depending on environmental conditions and the health of the chicken itself.

The quality of eggshells is important for transportation, storage, and processing. But, the color of the eggshell becomes one of the external features that most influence consumer acceptance (Altmann, Trinks, & Mörlein, 2023; Ibrahim & Ukasha, 2023). The shell is a protector of the main component in the egg that can protect the pressure from the external without cracking or breaking. The quality of the shell is important in the consumer perception (Eddin, Ibrahim, & Tahergorabi, 2019). Shell formation in the chickens takes 18 hours during one cycle and egg formation 24 hours. Shell color is an important parameter for determining the quality of egg (Lu et al., 2021; Samiullah, Roberts, & Chousalkar, 2016). It is also an important component in the reproductive system of poultry (Pruvost, Colin, Chevalier, & Faouën, 2022). The color of the shell in poultry is influenced by 2 pigments i.e. biliverdin and protoporphyrin (Drabik et al., 2021; Yu, Li, & Pan, 2016), besides that, the main packaging container and microbial barrier are very important for poultry producers. One of the naturally occurring factors and synthetic color of eggshell pigments – egg yolks red, orange, and yolk is that there are carotenoids in poultry feed additives (Berman et al., 2015; Samiullah, Roberts, & Chousalkar, 2015; Sandeski, Ponsano, & Neto, 2014).

One of the successful production indicators of laying hens is producing an average egg weight of 60 g/egg (Milenia, Madyawati, Achmad, & Damayanti, 2022). The average weight of chicken eggs is about 50 – 60 g. However, the weight of eggs can differ depending on the breed of chickens, the age of the chickens, and other factors such as feed, cage sanitation, and environmental conditions. The widespread industrialization of laying hens, and exploring to evaluate, predict, and improve egg quality during storage and processing are essential to provide public health security (Wu et al., 2024).

Eggshell quality is the most important aspect of consumers which is an indicator of purchasing power and has a positive influence on consumer preferences. Likewise the color of the shell, which is generally a more homogeneous brown color and is preferred by consumers (Loffredi, Grassi, & Alamprese, 2021). Orłowski et al. (2019) measured from capercaillies eggs in the form of egg size, egg weight, eggshell, and micro-nutrients of eggs and eggshells to see the quality of both. In the chicken egg industry, the commercial characteristics of eggshells in the form of physiology and biochemistry of brown pigment are important to look at about various functions (Samiullah et al., 2016). The moisture content of the shell decreases as the egg ages, mostly due to water evaporation through the shell's pores, which can have an impact on the shell's structural integrity and ability to protect the egg interior. There is no information regarding the identification of the eggshell quality of the Lohman Brown strain based on the age of the eggs after harvest which has been determined by the Indonesian National Standard (1 to 14 days).

This study makes a significant contribution to the field of poultry science by investigating the quality of Lohman Brown eggshells through novel methodologies, particularly the application of Nix sensor technology for precise color evaluations, which have been largely neglected in prior studies. The novelty of this study lies in the application of the Nix sensor for precise color measurement, addressing a significant gap in the existing literature. By examining shell characteristics of Lohman Brown eggs aged 1 to 14 days, this study provides unprecedented insights into how shell color and quality dynamically change over time. This detailed and methodical approach sets a new standard for future study in poultry science, enhancing our understanding of post-harvest egg quality and its implications for food safety, consumer preferences, and agricultural practices.

2. Materials and Methods

The methodology employed in this study is quantitative. Egg samples were randomly selected based on egg age, ranging from 1 to 14 days. In total, 460 egg samples were obtained from Lohman Brown strains kept in traditional farming in Gowa, South Sulawesi, Indonesia. These samples were derived from 153 sample eggs, and the process was repeated three times to ensure reliability and accuracy of the data. The study variables included egg index, shell weight, shell thickness. These samples underwent detailed measurements and testing. The egg index was calculated by measuring the length and width of each egg, while the shell weight was obtained by weighing the shell after peeling. The thickness of the shell was measured using a micrometer at three different points. Shell percentage was determined by calculating the proportion of shell weight to the total egg weight. Shell moisture content was analyzed by drying the shell in an oven until a constant weight was achieved, while shell ash content was measured by incinerating the shell in a muffle furnace and weighing the remaining ash. Shell calcium content was measured using titration or spectrophotometry methods.

2.1. Variable Measurement

Egg Weight

The egg weight was formulated using a digital scale. Weighing eggs with digital scales aims to measure egg weight accurately (Iqbal, Khan, Mukhtar, Ahmed, & Pasha, 2016).

Shell Weight

The weight of the shell was measured using a digital scale. Before weighing, the shell is thoroughly washed and then weighed (Caner & Yüceer, 2015).

Shell Percentage

The shell percentage was calculated using the formula 1 (Qurniawan, Ananda, Hifizah, Majid, & Baharuddin, 2022).

$$\text{Shell percentage (\%)} = \frac{\text{Shell weight (g)}}{\text{Egg weight (g)}} \times 100 \quad (1)$$

Note:

Shell Weight (g): The shell weight in grams
Egg Weight (g): The total egg weight in grams

Shape Index

Measurements of egg length and width were carried out with a digital caliper up to close to 0.01 mm. The egg shape index (SI) is determined from these measurements according to Anderson, Tharrington, Curtis, & Jones (2004) as given by formula 2.

$$SI = \frac{W}{L} \times 100 \qquad (2)$$

Note:

SI = Egg shape index
W = Wide egg
L = Egg length

Shell Thickness

Eggshells were cleaned with clean water and then dried before measuring. The thickness of the eggshell was measured using a digital micrometer. The measurement was carried out with the distance between the two surfaces of the eggshell, by placing the digital micrometer in the right position and parallel to the surface of the eggshell. After obtaining several measurements of eggshell thickness at several different points, the measurement results can be calculated as the average to obtain the overall eggshell thickness value (Fathi & Taghizadeh RahmatAbadi, 2024).

Eggshell Color

Egg shell color is an important external characteristic of eggs (H. Wang, Cahaner, et al., 2023). The color of the eggs was measured using a nix-sensor. Nix-sensor is a portable color measuring device that is used to identify colors and select a color palette according to necessity. The tool can be used in various fields, such as interior design, fashion, automotive, and others. Nix-Sensor worked by placing the tool on an object or eggshell surface, then the tool will take a color sample and show the results on the screen. The color of measurement results can be stored in the form of digital files for further use. Nix Sensor came with an extensive color database, including industry-standard colors, popular colors, and even custom user-created colors. The tool can also be used to identify colors on objects that haven't labels or color codes.

Eggshell Color Coordinate Measurement and Pigment Content Detection

The L*, a*, and b* values of each eggshell were measured by using a nix-sensor), at the site of the egg's air chamber. The shell color index (SCI) and blue-green chroma index (BGC) were calculated using formula 3 and 4, according to (H. Wang, Ge, et al., 2023).

$$SCI = L^*-a^*-b \qquad (3)$$

$$BGC = \sqrt{(a^*)^2 + (b^*)^2} \qquad (4)$$

Note:
SCI = Shell color index
BCG = Blue-green chroma index
L^* = Lightness
a^* = Redness
b^* = Yellowness

2.2. Statistical Analysis

The difference in eggshell characteristics in the shelf life was determined by analysis of variance (ANOVA) and If there was a significant difference analyzed by Duncan's multiple distance test. Statistical analysis was carried out by the SPSS version 24 software (Mestani et al., 2024).

3. Result and Discussion

Table 1 represents a comprehensive analysis of the correlation between the age of eggs and various attributes such as egg weight, shell weight, shell percentage, shell thickness, and shape index. The data, presented with mean values and standard deviations, reveal notable trends and variations in these attributes over the course of fourteen days. Such insights are valuable for understanding the impacts of egg aging on physical properties, which could inform best practices in egg storage and utilization.

Table 1. Quality of Lohman Brown strain eggs by storage life (Mean ± Std.v)

Age of eggs (days)	Egg Weight (g)	Shell Weight (g)	Shell Percentage (%)	Shell Thickness (mm)	Shape Index
1	62.19 ± 4.58^{c}	6.65 ± 0.64^{d}	10.74 ± 0.97^{ab}	0.43 ± 0.05^{b}	83.73 ± 3.66^{d}
2	62.21 ± 5.75^{c}	6.62 ± 0.60^{cd}	10.73 ± 1.60^{ab}	0.42 ± 0.05^{b}	77.01 ± 2.91^{abc}
3	61.31 ± 5.75^{c}	6.70 ± 0.51^{d}	10.97 ± 0.90^{abc}	0.45 ± 0.04^{b}	74.85 ± 3.41^{abc}
4	61.42 ± 4.03^{c}	6.52 ± 0.54^{bcd}	10.61 ± 0.62^{a}	0.74 ± 0.09^{d}	76.29 ± 5.03^{ab}
5	57.88 ± 4.96^{ab}	6.48 ± 0.63^{bcd}	11.21 ± 0.96^{abcd}	0.46 ± 0.07^{bc}	79.30 ± 4.36^{c}
6	57.99 ± 3.83^{ab}	6.61 ± 0.60^{cd}	11.40 ± 0.80^{cd}	0.48 ± 0.05^{c}	79.16 ± 2.07^{cd}
7	56.46 ± 4.72^{ab}	6.61 ± 0.79^{cd}	11.72 ± 1.26^{d}	0.47 ± 0.04^{c}	79.12 ± 4.30^{cd}
8	57.20 ± 3.87^{ab}	6.50 ± 0.47^{bcd}	11.31 ± 0.80^{cd}	0.47 ± 0.05^{c}	78.58 ± 2.15^{cd}
9	58.55 ± 3.96^{b}	6.44 ± 0.53^{bcd}	11.01 ± 0.76^{abc}	0.57 ± 0.06^{d}	78.87 ± 2.44^{cd}
10	57.55 ± 3.32^{ab}	6.44 ± 0.53^{bcd}	11.25 ± 1.32^{bcd}	0.57 ± 0.06^{e}	78.57 ± 3.22^{cd}
11	56.70 ± 3.99^{ab}	6.09 ± 0.60^{a}	10.75 ± 0.96^{ab}	0.43 ± 0.04^{b}	77.74 ± 2.73^{abc}
12	55.81 ± 4.60^{a}	6.28 ± 0.54^{abc}	11.28 ± 0.90^{cbd}	0.38 ± 0.04^{a}	78.83 ± 1.54^{cd}
13	56.69 ± 3.89^{ab}	6.21 ± 0.52^{ab}	10.98 ± 0.97^{abc}	$0.38a \pm 0.04^{a}$	78.08 ± 2.42^{abc}
14	55.95 ± 4.54^{ab}	6.37 ± 0.54^{abcd}	11.40 ± 0.86^{cd}	0.37 ± 0.04^{a}	75.69 ± 13.79^{a}

Note: The differences between values with different superscript letters in the same column were significant ($P<0.05$). Data sourced from the author's own study (2024).

3.1. Egg Weight

Egg weight was defined as the ratio of the width and length egg which was one of the important criteria in determining egg quality (Duman, Şekeroğlu, Yıldırım, Eleroğlu, & Camcı, 2016). The weight of eggs produced by chickens of the Lohman Brown strain varies depending on the age and the health of the chicken. At the beginning of the egg-laying period, usually, the weight of the eggs produced is smaller than at the peak of the egg-laying period. In general, the weight of Lohman Brown eggs ranges from 55 – 65 g/egg, with an average of about 60 g/egg (Table 1). However, it can also be influenced by genetic factors, chicken-rearing management, nutrition, and environmental factors such as temperature and humidity.

Based on the results obtained Table 1, the weight of eggs stored for 5 days was not significantly different from those stored for more than 5 days because the variations in egg weight over this period fall within the standard deviations, indicating that the storage duration does not have a substantial impact on the weight. There was a shrinkage of eggs from 1 to 14 days during storage. Egg weight from the 1 day ranges from 62 g to 14 days was 55.95 g. However, the quality of fresh eggs often decreases such as egg weight with long storage, causing a change in chemistry, function, nutrition, and hygiene, so this study in line with (Neto et al., 2024). However, these changes had a negative impact on the quality and value of commodities that can be consumed by humans (Xing, Niu, Su, & Yang, 2016). Egg weight affected the age of laying hens in the range of 30.22 – 32.19 g (Chung & Lee, 2014).

Egg storage can cause several changes to the quality and physical properties of eggs, including a decrease in egg weight and volume. Factors that affect egg shrinkage during storage include storage duration: The more the egg is stored, the more likely it is to shrinkage due to the process of water evaporation that occurs in the egg (Melo et al., 2021). Storage temperatures of eggs That are stored at high temperatures can cause a faster aging process in eggs, resulting in a decrease in egg weight and volume. High air humidity can result in condensation on the surface of the egg, which will reduce the weight and volume of the egg.

3.2. Shell Weight

Table 1 shows that the weight of the eggshell generally ranges from 8 to 12% of the total egg weight in laying breeds such as Lohmann Brown. Specifically, the weight of the shell can range from 6.87 g to as low as 5.04 g. The lower range of the eggshell weight found in laying hens is 5.04 g (Y. Wang et al., 2024). It is important to note that the measured parameters, such as eggshell weight and thickness, can significantly influence the egg storage life. Thicker and heavier eggshells typically provide better protection against microbial contamination and physical damage, thereby extending the shelf life of the eggs. Conversely, thinner and lighter eggshells may lead to increased fragility and susceptibility to spoilage, reducing the egg storage life (EFSA Panel on Biological Hazards (BIOHAZ), 2014).

3.3. Shell Percentage

The processing of eggshells into shell flour yields a substantial 55.26 % in the form of calcium carbonate, which underscores its efficiency (Table 1). This high yield is largely attributed to the shell's composition, which includes a variety of minerals. These minerals, primarily calcium carbonate, are responsible for the structural integrity and protective qualities of the eggshell. According to Qurniawan et al., (2022) the average eggshell weight produced in various countries ranges between 9 – 15 %, indicating that there is considerable variability based on geographical and environmental factors. The transformation of eggshells into shell flour not only provides a valuable source of calcium carbonate for various applications but also represents an effective way to utilize by-products of the poultry industry, thereby reducing waste and promoting sustainability (Aditya, Stephen, & Radhakrishnan, 2021). Additionally, understanding the mineral composition of eggshells can help in improving processing techniques and optimizing the quality of the product, ensuring it meets the required standards for its intended uses (Abdelgalil, Kaddah, & Abo-Zaid, 2024). The measured parameters, such as calcium carbonate content and eggshell weight, are directly related to egg storage life. High calcium carbonate levels enhance eggshell strength, which protects the egg from microbial contamination and physical damage, thus extending the egg's storage life. Conversely, variations in eggshell weight due to geographical and environmental factors can influence the durability and shelf life of the eggs (McClelland, Cassey, Maurer, Hauber, & Portugal, 2021).

3.4. Shape Index

Shape index or egg shape index was a measure used to measure the egg shape or proportion. The shape index was calculated by dividing the longest diameter of the egg by the diameter perpendicular to the longest diameter. The ideal egg shape index was in the range of 75 – 80 %, indicating that the egg had a round and symmetrical shape. The egg shape was too round or too oval and had a lower shape index. Table 1 showed that the range of shape index obtained at the first age reached 83.3 % and decreased at the 14th age to 75.69 %. This decrease can be attributed to several factors such as natural moisture loss, changes in egg internal pressure, and potential physical handling during storage, all of which can alter the egg's dimensions. According to Biggins, Thompson, & Birkhead (2018). Another comparison of the egg shape index in turkey eggs was found by Mróz, Stepińska, & Krawczyk (2014) ranges from 69 – 72 %, while in Japanese quail eggs was the range of 76,53 % (Narinc, Aygun, Karaman, & Aksoy, 2015). These comparisons highlight the variations in shape index across different bird species and the impact of aging on egg shape. The relationship between the measured parameters and egg storage life shows that as the shape index decreases due to aging and environmental factors, the structural integrity and quality of the eggs diminish, potentially reducing their shelf life

3.5. Shell Thickness

Eggshell thickness is an important metric in evaluating egg quality since it directly affects the egg's structural integrity and ability to shield the contents from microbiological contamination and physical damage. The data show that shell thickness varies dramatically over a 14-day period, with the highest thickness on day 4 (0.74 mm) and the lowest thickness on days 12, 13, and 14 (0.37 mm). The highest eggshell thickness observed on day 4 (0.74 mm) could be due to an optimal period in the hen's metabolic and calcium absorption cycle, which facilitates the formation of a thicker shell. In comparison, during the initial days (1-3) and later days (5-14), variations in dietary calcium uptake, metabolic efficiency, and possibly increased environmental or physiological stress may result in thinner shells. This peak on day 4 reflects a specific phase where conditions are most favorable for calcium deposition and shell formation (Milbradt et al., 2017).

These variances can be related to a variety of factors, including the availability of dietary calcium, hen age, environmental circumstances, and genetics. Adequate calcium intake is required for hens to create robust and thick shells, with younger hens often laying eggs with thicker shells than older hens. Temperature and humidity are two environmental stressors that can have an impact on shell quality, thus maintaining optimal circumstances for egg production is critical (Bain, Nys, & Dunn, 2016). The implications of these variations in shell thickness are substantial for both egg safety and economic reasons. Thicker shells protect the eggs from bacterial penetration and physical damage, ensuring their safety and quality (Cheng & Ning, 2023). To reduce breakage and economic losses, commercial egg producers must maintain constant shell thickness. Commercial egg producers can maintain constant shell thickness by ensuring hens receive a balanced diet rich in calcium and other essential nutrients, managing their health, maintaining optimal living conditions, and implementing genetic selection (Y.Nys, 2017). While shell thickness has no direct effect on the nutritional value of the egg, it does serve as an indicator of the hen's overall health and nutritional status. Understanding and regulating the elements that determine shell thickness can assist improve egg production procedures, resulting in higher-quality and safer eggs for customers (Cheng & Ning, 2023).

The thickness of the eggshell may differ depending on factors such as the age of the chicken, the genetics of the chicken, nutrition, environmental conditions, and maintenance management. In general, the shell of chicken eggs has a thickness of about 0.3 to 0.4 mm (Table 1). In eggshells in the range of 0.37 to 0.46 mm. This aligns with the findings of Ahmed, Tawfeek, Abou-Kassem; D E, & Bealish (2023) who report that the thickness of laying hen shells ranges from 0.21 to 0.30 mm. Furthermore, turkey eggshells typically range around 0.3 mm, as noted by (Mróz et al., 2014). Thus, the observed variations in eggshell thickness across different studies emphasize the influence of various biological and environmental factors

3.6. Eggshell Color

The color classification of Lohman Brown strain eggshells from 1 to 14 days post-harvest, categorized into dark brown, brown, and light brown with hex codes and sRGB values, showed in Table 2. This classification helps to understand temporal color changes for quality assessment and consumer preference.

Table 2. Classification color of egg Lohman Brown strain shells based on nix measurement results – sensor the eggs range 1 to 14 days old

Color Classification	Age (days)	Color (hex code)	sRGB R	sRGB G	sRGB B
Dark brown	6	#9F4047	159	64	71
	11	#9F4346	159	67	70
Brown	2	#B86B55	184	107	85
	3	#BC6E5A	188	110	90
	4	#B0574C	176	87	76
	5	#B05D4A	176	93	74
	7	#B35B52	179	91	82
	8	#B46352	180	99	82
	9	#B26158	178	97	88
	10	#B05E4B	176	94	75
	12	#B26344	178	99	68
	13	#A95848	169	88	72
	14	#A25140	162	81	64
Light brown	1	#C78D6D	199	141	109

Note: Data sourced from the author's own study (2024). sRGB R=Red; sRGB G=Green; sRGB B= Blue.

Table 2 categorizes Lohman Brown strain eggshells by color based on age, from 1 to 14 days, using Nix sensor measurements. It details classifications such as dark brown, brown, and light brown with corresponding hex codes and sRGB values. For instance, 6-day eggs are dark brown (#9F4047) while 1-day eggs are light brown (#C78D6D). Over time, eggshells darken, with 14-day eggs showing a more saturated brown (#A25140). This classification aids in assessing eggshell quality for consumer markets as color consistency affects marketability.

Figure 1 displays the 3D scatter plot of Lohman Brown strain eggshell colors based on sRGB values, categorized by age from 1 to 14 days post-harvest. Each sphere represents an egg sample, with colors and labels indicating age and hex codes. The axes correspond to sRGB RED, GREEN, and BLUE values, revealing variations and trends in eggshell color with aging, thereby supporting the study's analysis of eggshell quality dynamics.

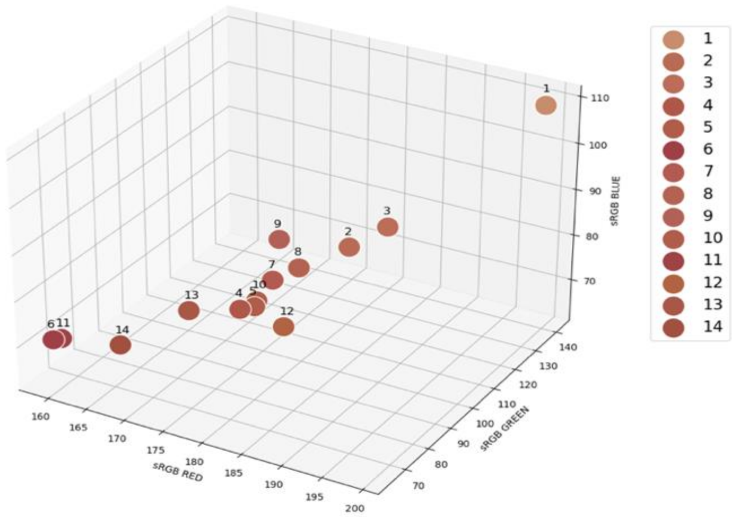

Figure 1. Egg color analysis using 3D scatter plot matplotlib

Eggshells usually had different colors, depending on the type of chicken that produces the egg. The color of the eggshell may range from white, brown, green, and blue, to purple. The color of the eggshell can give clues about the nutritional egg content, but it didn't give a definite indication of the egg quality or freshness. Eggshell color measurement can be useful in several of applications, such as in the food and beverage industry, animal husbandry, and scientific research. The color of the eggshell can give an indication of the state of health of the pet or the quality of nutrition in the food produced from the animal. Using this technique, we can visualize the color distribution in the egg and analyze the color patterns formed. For example, we may see the color differences between eggs produced by chickens with different genetics or eggs produced from different environments or may see differences in egg color based on shelf life. The coloring functions of eggshells may range from those related to the physical properties of pigments i.e., filtering solar radiation or strengthening the eggshell to those related to the adaptive function of color (Holveck, Guerreiro, Perret, Doutrelant, & Grégoire, 2019). The color of the eggshell was largely due to the deposition of pigments, one of the pigments was the antioxidant biliverdin (Hargitai, Boross, Nyiri, & Eke, 2016).

Wide variations in shell color and pigment patterns arise from three molecules, protoporphi rin, biliverdin, and zinc biliverdin chelate. Biliverdin is most likely synthesized in the uterus. Although protoporphyrins were also synthesized in the uterus, the evidence was more circumstantial. The pigment was secreted from epithelial cells of the uterine surface into the uterine fluid directly into the shell. The tissue content of protoporphyrin white-shelled chickens was not different from the brown-shell egg chickens. Shell pigment was usually stained within 24 hours of laying eggs (Dominguez-Gasca, Muñoz, & Rodriguez-Navarro, 2017). The color of the eggshell was affected by the pigments secreted by the glands in the oviduct of the chicken. The color of the eggshell may range from white to dark brown depending on the breed of chicken and the pigment content it has.

3.7. Eggshell Color Coordinate Measurement and Pigment Content Detection

Table 3 details changes in eggshell color and quality parameters of Lohman Brown eggs over 14 days, measuring lightness, color components and, shell color intensity. This data highlights the temporal changes in eggshell properties, emphasizing the importance of monitoring egg quality and consumer appeal in the poultry industry.

Table 3. Means of the eggshell color by nix-sensor

Index	Egg age													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Shell color													
L^{*2}	64	54	55	48	49	41	50	51	51	50	41	51	47	45
a^{*2}	20	30	30	36	33	41	35	32	33	33	40	30	33	33
b^{*2}	27	27	25	24	27	17	22	25	21	27	18	32	25	26
SCI^2	17	-3	0	-12	-11	-17	-7	-6	-3	-10	-17	-11	-11	-14
BGC^2	749	759	655	612	762	330	519	657	474	762	364	1054	658	709

Note: Each value is the mean from twelve hens, each hen used the mean of its three eggs. SCI = shell color index; BGC = blue-green chroma index; L* = lightness; a* = redness; b* = yellowness. Data sourced from the author's own study (2024).

The correlation between the parameters L*, a*, and b* can help identify the relationship pattern between brightness and the color components of the eggshell. if there is a strong negative correlation between L* and a*, this may mean that the lighter the eggshell, the less red color there is in the egg. It is a neutral indication. It suggests an observed correlation between the lightness of the eggshell and the amount of red color in the egg without implying that this relationship is necessarily good or bad. It is important to remember that factors such as chicken breed, feed type, determined by pigments and environmental conditions could affect eggshell color (Abebe, Mulatu, & Kelemework, 2023; Rizzi, Cendron, Penasa, & Cassandro, 2023).

4. Conclusion

Based on the measured parameters and their statistical analysis, the ideal shelf life of eggs is up to 12 days. Beyond this period, the quality indicators such as shell thickness and shape index significantly decline, potentially compromising the eggs' structural integrity and safety. The color of the eggs based on the typical Lohmann chicken pattern was brown, which is not homogeneous based on age, but further recommendations are needed using digital image analysis.

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