

Evaluation of physical quality and chemical composition of commercially available table eggs

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ABSTRACT

A variety of commercial table eggs are available in retail outlets, but little information is available on their physical quality and chemical composition. In this study, 49 eggs were analysed, divided into three types (conventional, organic and omega-3 rich) and three grades (A, B and C). The quality of the eggs was assessed on the basis of physical structure and chemical composition. No significant ($p > 0.05$) differences were found in egg weight, shell weight, yolk height, albumen height, shell thickness, shape index and Haugh unit between egg types, regardless of grade. Similarly, no significant ($p > 0.05$) differences were found between grades A and B for most parameters except shell weight. In the traditional eggs, grade A had a higher ($p < 0.05$) egg weight and albumen height than grades B and C. For organic eggs, grade A showed significantly ($p > 0.05$) higher egg weight, yolk index, yolk height and Haugh unit than grade B. In the omega-3 rich eggs, grade A had greater ($p < 0.05$) egg weight, albumen height, and yolk height, while grade B had a higher Haugh unit than grade A. No significant ($p > 0.05$) differences were found between the egg types in dry matter, protein and fat contents of the albumen and yolk. However, ash content of the yolk was significantly ($p < 0.05$) higher in organic eggs (2.4%) compared to omega-3 rich (2.1%) and conventional eggs (1.8%). In conclusion, while most physical traits did not vary significantly across egg types and grades, notable differences in yolk ash content suggest variations in mineral composition. These findings are relevant to consumers seeking nutrient-dense options and to producers aiming to enhance egg quality and market value.

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1. INTRODUCTION

In recent years, consumer's awareness of health and nutrition has increased significantly, leading them to scrutinise their food choices and preferences ever more closely. This trend is accompanied by a parallel interest in affordability, leading consumers to look for foods that offer a balance between nutritional and economic value. Among animal foods, eggs remain a widespread and easily accessible source of high-quality nutrients, as they contain important proteins, vitamins, minerals, cholesterol and fatty acids that are beneficial to human health (Tian et al., 2022). Chicken eggs are considered a staple food worldwide due to their affordability, versatility and dense nutritional profile.

However, the modern egg market has expanded beyond conventional eggs to include a variety of speciality products such as organic eggs and omega-3 enriched eggs, which are marketed based on perceived health benefits and production standards. These eggs are offered in different

quality grades (e.g. AA, A, B and C) and their prices vary depending on factors such as production system, feed type, transport logistics and consumer demand (Harnsoongnoen & Jaroensuk, 2021; Maina et al., 2023). While consumers are increasingly attracted to premium eggs under the assumption of better quality, many of them remain uncertain about the actual differences in nutritional value and quality of the different types and grades of eggs available on the market.

The quality of eggs includes both external (morphological) characteristics, such as cleanliness, firmness and shape of the shell, and internal characteristics such as the viscosity of the albumen and the integrity of the yolk membrane, which are critical for both consumer satisfaction and food safety (Tougan & Thewis, 2024). Importantly, factors such as storage conditions, hen breed, age and diet can significantly affect the quality of eggs after laying (Lee et al., 2016). Consumers may look at the appearance of the shell when purchasing, but the internal quality, which deteriorates

over time if not handled properly, is a more critical factor affecting edibility, nutritional content and overall value.

Although numerous studies had investigated the influence of chicken feed and farming systems on egg quality (e.g. organic versus conventional chicken farming), comprehensive comparisons between different types and qualities of commercially available eggs are still limited, especially in the Southeast Asian context. For example, the studies by Zahira et al. (2021) and Sze et al. (2018) provided initial insights into the quality of eggs in Malaysia, but did not fully investigate the relationship between egg type and variety in terms of morphological and chemical parameters. Cicek and Kartalkanat (2009) also emphasised the need for more detailed comparisons between village eggs and commercial eggs, but such comparisons are not yet sufficiently explored, especially given the influx of enriched eggs such as omega-3 variants.

To date, there is a lack of up-to-date and comprehensive data on the morphological characteristics and chemical composition of the different egg types (conventional, organic, omega-3 enriched) in the commercial grades (A, B and C) in the Malaysian retail market. This information is important not only to help consumers make informed purchasing decisions, but also to assist producers and policy makers in setting prices, quality standards and labelling requirements. This study addressed the following research questions: (1) Are there significant differences in physical and chemical properties between conventional, organic and omega-3 eggs in different grades? (2) How do these differences affect consumer value and quality assurance? The main objective was to provide consumers and producers with comprehensive data to inform decisions and policies. Unlike previous studies that focused on individual egg types or did not differentiate between grades, this study examined both egg type and grade under real market conditions in Malaysia, providing a novel and practical contribution to this topic.

2. MATERIALS AND METHODS

This study was conducted in the laboratory of the Faculty of Agro Based Industry, Universiti Malaysia Kelantan, Kelantan, Malaysia. On a single day, local grocery shops were visited to purchase commercially available table eggs of the following grades and qualities: conventional eggs (grades A, B and C), organic eggs (grades A and B) and omega-3 rich eggs (grades A and B). The study was conducted using a completely randomized design with 7 treatments, consisting of three main egg types (conventional, organic and omega-3 rich) and three egg grades (A, B and C) as sub-treatments, each with 7 replicates. The sample size (n=49) was determined based on common practise in similar egg quality studies,

which typically use 6–10 replicates per treatment group to ensure a reliable comparison (Safaa et al., 2008). Although no formal power analysis was performed, the number of replicates was sufficient to detect significant differences in physical and chemical characteristics between treatment groups. No grade C samples were taken from organic eggs and eggs with high omega-3 content as these were not available on the local market at the time of sampling. This represents a limitation in the study design as it restricts the ability to fully compare all egg types across all commercial grades. As a result, the conclusions regarding grade-specific trends in organic and omega-3 eggs may not be generalisable beyond grades A and B. Nevertheless, the study provided valuable comparative insights within the constraints of actual market availability.

Eggs were purchased and stored at 4°C until analysed the following morning. All eggs were analysed within 24 hours of purchase to minimise variation in freshness measurements. The protocol described by Altunatmaz et al. (2020) was followed. To minimise confounding factors, all eggs were purchased on the same day and under similar retail conditions and analysed under identical laboratory protocols. Only intact, visibly undamaged eggs were selected to ensure consistency. Eggs from each treatment group were randomised prior to testing to avoid bias. During the test, only forty-nine (49) intact eggs without cracks were used for the study. The age of the eggs was determined by the time span between the processing date on the carton and the date the eggs were purchased. The physical quality of the eggs was determined by weighing the egg, the albumen, the yolk and the shell. The egg shape index, the yolk index, the Haugh unit, the shell thickness, the albumen, yolk and shell content were measured and calculated. The yolk index (YI) was determined by dividing the yolk height by the yolk diameter of the egg cracked on a flat surface according to the following formula described by Alkan and Turker (2021). The chemical composition consisting of the moisture, protein, fat and ash contents of the albumen and yolk, was determined according to the method of AOAC (2012).

$$YI = \frac{Y_h}{Y_w} \times 100$$

Where,

Y_h = yolk height (mm); Y_w = yolk width (mm)

The Haugh unit (HU) was calculated using the following formula as described by Alkan and Turker (2021):

$$HU = 100 \times \log_{10} (H - 1.7 \times W^{0.37} + 7.57)$$

Where,

HU = Haugh unit; H = observed albumen height (mm);
W = egg weight (g)

Shell thickness was measured at three points (blunt, equatorial and pointed end) using a micrometre screw (± 0.01 mm), and the mean value was recorded as described by Alkan and Turker (2021). The shell weight (SW) was calculated according to the following formula described by Harms (1990):

$$SW = (2.034 \times Ew) - \left(\frac{2.1014 \times Ew}{SG} \right)$$

Where,

Ew = weight of the egg (g); SG = specific gravity of the egg in g/cm³

The length and width of the eggs were measured to the nearest 0.01 mm using a Vernier scale. According to Alkan and Turker (2021), the shape index of the eggs was calculated using the following formula:

$$\text{Shape index (\%)} = (\text{egg width} / \text{egg length}) \times 100$$

All data were analysed by one-way ANOVA using SPSS software (version 26.0). Assumptions of normality and homogeneity of variance were tested prior to analysis. Differences between treatments were compared using Duncan's Multiple Range Test at $p < 0.05$.

3. RESULTS AND DISCUSSION

This study provided a comprehensive assessment of the physical and chemical properties of commercially available table eggs, namely organic, omega-3 rich, and conventional eggs, including the grading levels (A, B, C), an aspect often overlooked in previous studies. While previous studies had mainly focused on the effects of factors such as hen breed, feed composition, laying cycle or storage conditions (Yuan et al., 2023; Hejdysz et al., 2024; Kim et al., 2024), there is a lack of published data examining how these egg types perform in the retail market depending on classification. This study therefore filled a notable research gap by investigating the combined effect of egg type and grade on physical and chemical quality parameters under real-market conditions.

3.1 Physical quality characteristics

3.1.1 Egg weight, albumen height, yolk height

As shown in Table 1, egg weight, albumen height, and yolk height differed significantly ($p < 0.05$) between the treatments. For grade A eggs, omega-3 rich eggs consistently had a higher egg weight (72.0 g) and albumen height (7.8 mm) than organic (59.3, 7.6 mm) and conventional eggs (54.7 g, 4.8 mm), respectively. A similar trend was observed for grade B eggs, where omega-3 rich eggs again performed better than the other types. For all egg types, both egg weight and albumen height increased progressively from grade C to grade

A. However, when egg grading was not taken into account, the differences in egg weight and albumen height between the sources were not significant ($p > 0.05$).

In contrast to Albader et al. (2024), who reported that higher egg weight may reduce albumen height due to dilution or ageing, our study found that omega-3-rich eggs had both higher weight and albumen height, particularly in grades A and B. This inconsistency could be due to differences in breed, diet or storage. It suggests that the relationship between egg weight and albumen height may vary depending on the production system and rearing conditions.

Albader et al. (2024) found similar results in Riyadh, where eggs from supermarkets had the highest weights, while organic eggs had a higher albumen percentage. The mean egg weights in the present study were consistent with the range of 51.82 g to 63.05 g as reported by Albader et al. (2024). Hisasaga et al. (2020) also reported that organic cage-free eggs (brand D) had the highest average weight (62.4 g), ahead of enriched cage-free eggs (brand C) at 59.6 g. Among the physical quality characteristics of eggs, the height of the albumen and the thickness of the shell are important indicators of freshness and structural integrity. The height of the albumen reflects the internal quality of the egg, while the thickness of the shell contributes to protect against microbial contamination and moisture loss, both of which can indirectly affect the quality of the albumen over time. Notably, some studies had shown that eggs with thicker shells, such as those from organic or free-range systems, often maintain higher albumen heights during storage due to reduced moisture loss and gas exchange (Hejdysz et al., 2024). Kim et al. (2024) showed that refrigerated storage helps to preserve albumen height, while Rho and Cho (2024) observed that shell quality influences how quickly albumen height declines. These findings support the interconnected role of shell thickness and albumen height in maintaining egg quality across different egg types and production systems.

In terms of yolk height, omega-3 rich and conventional eggs showed higher values than organic eggs in Grade A. This trend continued in Grade B, with omega-3 rich eggs recording the highest yolk height (18.8 mm), followed by conventional (17.1 mm) and organic (12.9 mm). Yolk height was significantly higher in Grade A than Grade B for both organic and omega-3 enriched eggs, while conventional eggs showed no significant ($p > 0.05$) difference between grades. Yolk height, a vital indicator of quality, varies across egg types and grades. Hisasaga et al. (2020) found the highest yolk heights in conventional white and brown eggs (24.3 mm and 24.5 mm, respectively), while pasture-raised eggs had the lowest (20.1 mm). Zita et al. (2022) further demonstrated that hen age affects yolk height and other internal quality traits, where older hens producing eggs with altered yolk proportions.

Visual comparisons of egg weight and albumen height among treatments are presented in Table 1, showing the variation across egg types and grades. It clearly stated that omega-3 rich eggs consistently exhibited the highest values, especially in Grade A.

Table 1: Effect of egg grading on egg weight, albumen height and yolk height values in different sources of eggs.

| Parameter | Grading of egg (mean ± standard deviation) | | | Overall mean | Significance level |
|----------------------------|---|---------------------------|-------------------------|--------------|--------------------|
| | A | B | C ^β | | |
| Egg weight (g) | | | | | |
| Conventional egg | 54.7 ± 0.58 ^{aC} | 51.7 ± 0.58 ^{bB} | 45.0 ± 1.0 ^c | 50.4 ± 4.33 | p<0.01 |
| Organic egg | 59.3 ± 1.15 ^{aB} | 52.3 ± 1.15 ^{bB} | | 55.8 ± 3.97 | p<0.01 |
| Omega-3 rich egg | 72.0 ± 1.0 ^{aA} | 57.7 ± 1.15 ^{bA} | | 64.8 ± 7.91 | p<0.01 |
| Overall mean (g) | 62.0 ± 7.81 | 53.9 ± 2.98 | | 56.1 ± 8.02 | p>0.05 |
| Significance level | 0.000 | 0.001 | | 0.129 | |
| Albumen height (mm) | | | | | |
| Conventional egg | 4.8 ± 0.32 ^{aB} | 4.4 ± 0.03 ^{bB} | 4.3 ± 0.05 ^c | 4.5 ± 0.24 | p<0.05 |
| Organic egg | 7.6 ± 0.14 ^A | 7.2 ± 0.61 ^A | | 7.4 ± 0.45 | p>0.05 |
| Omega-3 rich egg | 7.8 ± 0.13 ^{aA} | 7.4 ± 0.02 ^{bA} | | 7.6 ± 0.22 | p<0.01 |
| Overall mean (mm) | 6.7 ± 1.45 | 6.3 ± 1.47 | | 6.3 ± 1.56 | p>0.05 |
| Significance level | 0.000 | 0.000 | | 0.699 | |
| Yolk height (mm) | | | | | |
| Conventional egg | 18.1 ± 0.61 ^A | 17.1 ± 0.94 ^B | 16.5 ± 0.31 | 17.2 ± 0.93 | p>0.05 |
| Organic egg | 17.5 ± 0.9 ^{aB} | 12.9 ± 0.44 ^{bC} | | 15.2 ± 2.62 | p<0.01 |
| Omega-3 rich egg | 20.4 ± 0.74 ^{aA} | 18.8 ± 0.4 ^{bA} | | 19.6 ± 0.99 | p<0.05 |
| Overall mean (mm) | 18.7 ± 1.46 | 16.3 ± 2.7 | | 17.3 ± 2.28 | p>0.05 |
| Significance level | 0.008 | 0.000 | | 0.088 | |

^{a,b,c}Means within a row with different superscripts differ significantly (p<0.05).
^{A,B,C}Means within a column with different superscripts differ significantly (p<0.05).
^βGrade C samples were unavailable for organic and omega-3 eggs due to market limitations.

3.1.2 Shell weight and shell thickness

In this study, Grade A egg shell weights are shown to be heavier than Grade B eggs, regardless of egg type (Table 2). However, shell weight did not differ significantly (p>0.05) among the different egg types. Yahaya et al. (2024) reported that shell thickness varied by breed, with White Leghorn hens producing consistently thick shells (49-53 mm), while Plymouth Rock hens showed an increase from 41 to 50 mm over time.

Shell thickness was consistently thicker in conventional eggs across both Grade A and B, compared to organic and omega-3 rich eggs. Yet, when data were pooled across all grades and sources, these differences were not statistically significant (Table 2). Yahaya et al. (2024) similarly noted that shell thickness can vary with breed and age,

underscoring genetic influences on shell quality.

Table 2: Effect of egg grading on shell weight and shell thickness values in different sources of eggs.

| Parameter | Grading of egg (mean ± standard deviation) | | | Overall mean | Significance level |
|-----------------------------|---|---------------------------|--------------------------|--------------|--------------------|
| | A | B | C ^β | | |
| Shell weight (g) | | | | | |
| Conventional egg | 1.0 ± 1.00 | 0.7 ± 0.58 | 2.3 ± 0.58 | 1.3 ± 1.00 | p>0.05 |
| Organic egg | 2.7 ± 1.53 | 1.3 ± 1.53 | | 2.0 ± 1.55 | p>0.05 |
| Omega-3 rich egg | 0.7 ± 1.15 | 1.3 ± 0.58 | | 1.0 ± 0.89 | p>0.05 |
| Overall mean (g) | 1.4 ± 1.42 ^a | 1.1 ± 0.93 ^b | | 1.4 ± 1.16 | p<0.05 |
| Significance level | 0.195 | 0.171 | | 0.330 | |
| Shell thickness (mm) | | | | | |
| Conventional egg | 0.17 ± 0.01 ^{aA} | 0.13 ± 0.02 ^{aA} | 0.12 ± 0.01 ^b | 0.14 ± 0.03 | p<0.01 |
| Organic egg | 0.10 ± 0.06 ^B | 0.10 ± 0.01 ^B | | 0.10 ± 0.01 | p>0.05 |
| Omega-3 rich egg | 0.10 ± 0.06 ^B | 0.10 ± 0.00 ^B | | 0.10 ± 0.00 | p>0.05 |
| Overall mean (mm) | 0.13 ± 0.03 | 0.11 ± 0.02 | | 0.12 ± 0.02 | p>0.05 |
| Significance level | 0.000 | 0.026 | | 0.506 | |

^{a,b}Means within a row with different superscripts differ significantly (p<0.05).
^{A,B}Means within a column with different superscripts differ significantly (p<0.05).
^βGrade C samples were unavailable for organic and omega-3 eggs due to market limitations.

Eggshell formation is closely linked to calcium homeostasis. Nik et al. (2024) highlighted the vital role of vitamin D₃ metabolites – especially 1α-hydroxycholecalciferol (1αOHD₃) - in enhancing calcium and phosphorus metabolism. This compound upregulates calcium transport genes such as Calbindin and TRPV6, improving calcium absorption and eggshell integrity in laying hens. Supporting this, Qiu et al. (2024) reported that dietary calcium lactate supplementation enhanced eggshell strength and laying performance, particularly in aged hens, by enhancing calcium bioavailability. Environmental factors like heat stress also affect calcium metabolism. Elevated temperatures reduce feed intake and lower calcium availability, impairing specific shell quality traits such as shell thickness, strength, and integrity, which are critical for minimizing breakage and preserving the internal egg quality.

Jiang et al. (2015) demonstrated that dietary supplementation with sodium bicarbonate (3 g/kg) during peak production improved calcium absorption and shell characteristics by boosting calcium-binding protein expression in the intestine. Similarly, Wakchaure (2023) reviewed that maintaining electrolyte balance through sodium bicarbonate and potassium chloride supplementation can alleviate heat stress, improving both laying performance and egg shell quality. These findings are particularly relevant when considering organic and omega-3-rich diets, which often differ in mineral composition and fat sources, potentially influencing

shell thickness through effects on calcium metabolism and absorption. Additionally, egg size influences shell characteristics. Yahaya et al. (2024) observed that larger eggs typically exhibit lower shell percentages, increasing their susceptibility to cracks during handling. These findings emphasize the need to consider egg size in quality assessment and packaging to reduce breakage risks, especially in premium eggs like organic and omega-3-enriched types where shell quality may vary due to dietary factors.

Storage conditions play a crucial role in maintaining HU. An et al. (2023) showed that refrigerated eggs maintained higher HU values over time compared to those stored at room temperature. Additionally, Menezes et al. (2012) found that eggs from younger hens had higher HU values, which decline with hen's age, regardless of storage condition. These findings highlight the combined influence of genetics, age, and post-harvest handling on egg freshness and internal quality.

3.1.3 Yolk index, shape index, Haugh unit (HU)

Regarding the yolk index (Table 3), the highest yolk index ranked by omega-3 rich > conventional > organic egg. Grade A organic eggs had a higher yolk index than Grade B organic eggs. However, no differences were observed between grades for conventional and omega-3 rich eggs. Overall, yolk height values among treatments were not significantly different ($p>0.05$). According to DSM Nutritional Products Ltd. (2022), yolk index values for regular, fresh and extra-fresh eggs are <0.28, between 0.29 – 0.38 and >0.38, respectively. The yolk index is a reliable indicator of freshness, and it is decreasing with storage time and temperature.

The egg shape index (SI) is an important criterion in determining egg quality. According to Duman et al. (2016), eggs are classified as sharp ($SI < 72$), normal ($SI = 72-76$), or round ($SI > 76$). In this study, SI ranged from 75.2 to 82.6 and did not differ significantly ($p>0.05$) among treatments (Table 3), indicating consistent egg shape across sources. These values align with Duman et al. (2016) and suggest proper handling and reduced breakage risk during transportation.

The HU, a key indicator of protein quality and egg freshness, is influenced by various factors, including storage conditions, hen age, and breed. In this study, organic eggs showed the highest HU in Grade A (87.6), while omega-3 rich eggs led in Grade B (86.8). Conventional eggs consistently recorded lower HU values across all grades. These trends align with Romero et al. (2024), who reported that hen genetics significantly affect albumen height and HU, with certain breeds exhibiting higher values in fresh eggs. Despite these trends, no significant differences in HU values were found among treatments regardless of egg type and grade. The overall HU value was 78.6, indicating good freshness.

Yuan et al. (2023) observed that HU values decline gradually from 85 on day 1 to 79 on day 7, then sharply to 70 by day 9, emphasizing the impact of storage duration on quality.

The findings reveal that omega-3 rich eggs are consistently superior to conventional and organic eggs in terms of egg weight, albumen height, yolk height, and yolk index, particularly within Grade A and B classifications. While differences were less pronounced or statistically non-significant when grades were not considered, this underscores the importance of grading in determining the quality traits of table eggs. This aspect is novel as most earlier studies had not stratified their analysis by egg grade, even though grading is a standard practice in commercial egg distribution and directly influences consumer perception and pricing.

Table 3: Effect of egg grading on yolk index, shape index and Haugh unit values in different sources of eggs.

| Parameter | Grading of egg (mean ± standard deviation) | | | Overall mean | Significance level |
|--------------------|---|----------------------------|--------------------------|---------------|--------------------|
| | A | B | C ^β | | |
| Yolk index | | | | | |
| Conventional egg | 0.468 ± 0.01 ^A | 0.459 ± 0.02 ^B | 0.45 ± 0.01 | 0.459 ± 0.01 | $p>0.05$ |
| Organic egg | 0.457 ± 0.03 ^{ab} | 0.362 ± 0.02 ^{bc} | | 0.409 ± 0.06 | $p<0.01$ |
| Omega-3 rich egg | 0.531 ± 0.02 ^A | 0.536 ± 0.01 ^A | | 0.534 ± 0.01 | $p>0.05$ |
| Overall mean | 0.485 ± 0.04 | 0.452 ± 0.077 | | 0.466 ± 0.057 | $p>0.05$ |
| Significance level | $p<0.01$ | $p<0.01$ | | $p>0.05$ | |
| Shape index | | | | | |
| Conventional egg | 78.9 ± 2.40 | 81.3 ± 2.43 | 75.9 ± 3.24 | 78.7 ± 3.35 | $p>0.05$ |
| Organic egg | 76.8 ± 2.63 | 82.6 ± 3.04 | | 79.7 ± 4.07 | $p>0.05$ |
| Omega-3 rich egg | 75.2 ± 2.19 | 77.2 ± 6.00 | | 76.2 ± 4.16 | $p>0.05$ |
| Overall mean | 77.0 ± 2.65 | 80.4 ± 4.30 | | 78.3 ± 3.87 | $p>0.05$ |
| Significance level | $p>0.05$ | $p>0.05$ | | $p>0.05$ | |
| Haugh unit | | | | | |
| Conventional egg | 69.2 ± 0.49 ^{ac} | 67.5 ± 0.52 ^{bc} | 69.0 ± 0.79 ^a | 68.5 ± 0.98 | $p<0.05$ |
| Organic egg | 87.6 ± 0.52 ^{aA} | 85.3 ± 0.2 ^{bB} | | 86.4 ± 1.32 | $p<0.01$ |
| Omega-3 rich egg | 85.1 ± 0.5 ^{bB} | 86.8 ± 0.35 ^{aA} | | 85.9 ± 1.02 | $p<0.01$ |
| Overall mean | 80.6 ± 8.67 | 79.8 ± 9.33 | | 78.6 ± 9.01 | $p>0.05$ |
| Significance level | $p<0.05$ | $p<0.05$ | | $p>0.05$ | |

^aMeans within a row with different superscripts differ significantly ($p<0.05$). ^{ABC}Means within a column with different superscripts differ significantly ($p<0.05$). ^βGrade C samples were unavailable for organic and omega-3 eggs due to market limitations.

In contrast to earlier studies that mainly examined single sources or homogeneous production systems (Hisasaga et al., 2020; Albader et al., 2024), the current study's approach of analysing eggs from diverse production systems available in the local market allows for a more realistic quality assessment available to consumers. This is

particularly relevant in the context of rising consumer interest in egg quality, nutritional value, and production ethics, as well as retail-level decision-making. As such, this research offers practical insights for both consumers and retailers by identifying the distinct physical and compositional profiles associated with different egg categories and grades.

Another novel observation was the evaluation of shell weight and thickness in relation to grade, showing that Grade A eggs had significantly heavier shells regardless of type, but conventional eggs exhibited thicker shells across grades. These findings provide actionable knowledge for improving egg handling, packaging, and transportation strategies, particularly for higher-grade eggs, and add nuance to the existing body of literature that usually attributes shell traits solely to hen genetics or age (Yahaya et al., 2024; Qiu et al., 2024). Table 3 displays the HU values across egg types and grades, highlighting that although differences were not statistically significant, organic Grade A eggs tend to have higher tendencies.

3.2 Chemical Composition

The contents of DM, fat, protein and ash in egg albumen and yolk of table eggs laid by hens from various sources are presented in Table 4. The chemical composition results showed minor variations across egg types, although most differences were not statistically significant. In this study, the DM content of albumen ranged from 15.0% to 17.2%, which was higher than the values reported by Hammersoj et al. (2022) who reported albumen DM content ranging from 13.08% to 13.58% across different hen genotypes in organic egg production systems. These discrepancies may be attributed to factors such as breed differences, diet, or environmental conditions. The yolk DM content in this study ranged from 48.3% to 51.7%, aligning with values (47.27% to 48.08%) reported by Filipiak-Florkiewicz et al. (2024), indicating that the variations observed are within the normal range for egg components.

Fat content in yolk ranged narrowly from 55.8% to 57.3%, with omega-3 rich eggs tending towards lower fat content, though differences were not significant. Albumen fat content was similarly stable across treatments and the values varied from 0.96% (conventional and omega-3 rich) to 1.0% (organic). Similar quantities (59.4%) of yolk fat and albumen fat (1.5%) were reported by Réhault-Godbert et al. (2019).

The protein content in yolk and albumen found to be non-significant ($p>0.05$) differences among different egg sources. The protein values for yolk and albumen vary from 38.7% to 40.2% and 96.7% to 97.9%, respectively. The protein content determined in the yolk in this study is in line with Réhault-Godbert et al. (2019), who reported that the protein content in yolk was 34.5%. However, in the present

study, the protein content of albumen was substantially higher than the value (88.1%) reported by Réhault-Godbert et al. (2019). This difference could be attributed to several factors, including variations in hen diet, age, genetic background, environmental conditions, and the analytical methods used for protein determination.

Table 4: Effect of egg sources on nutritional values (% dry matter basis) of egg yolk and egg albumen regardless of egg grades.

| Parameter | Sources of egg (mean ± standard deviation) | | | Overall mean | p-value |
|-------------------------|---|-------------------------|------------------|--------------|---------|
| | Conventional egg | Organic egg | Omega-3 rich egg | | |
| Yolk | | | | | |
| Dry matter ^a | 51.0 ± 5.20 | 48.3 ± 2.63 | 51.7 ± 7.75 | 50.4 ± 5.44 | p>0.05 |
| | 38.7 ± 0.65 | 39.5 ± 0.72 | 40.2 ± 0.38 | 39.5 ± 0.75 | |
| Protein | 57.3 ± 1.03 | 56.5 ± 0.7 | 55.8 ± 1.34 | 56.5 ± 1.13 | p>0.05 |
| | 1.8 ± 0.12c | 2.4 ± 0.04 ^a | 2.1 ± 0.24b | 2.1 ± 0.24 | |
| Ash | 17.2 ± 4.08 | 15.9 ± 4.10 | 15.0 ± 2.05 | 16.2 ± 3.58 | p>0.05 |
| | 96.7 ± 0.72 | 97.9 ± 0.52 | 96.9 ± 0.57 | 97.2 ± 0.57 | |
| Fat | 0.96 ± 0.01 | 1.0 ± 0.03 | 0.96 ± 0.03 | 0.97 ± 0.03 | p>0.05 |
| | 1.0 ± 0.05 | 0.9 ± 0.09 | 0.9 ± 0.08 | 0.9 ± 0.07 | |
| Ash | 1.0 ± 0.05 | 0.9 ± 0.09 | 0.9 ± 0.08 | 0.9 ± 0.07 | p>0.05 |
| | | | | | |

^{abc}Means with different superscripts in a row differ significantly ($p<0.05$). ^a, wet weight basis.

On the other hand, such differences were found on ash content in yolk. The highest value was observed in the organic eggs (2.4%), while the lowest in conventional eggs (1.8%). However, no difference was found on ash content in albumen among different egg sources, and the values varied from 0.9% to 1.0%. Albumen ash content remained uniform across all egg types. It is known that egg is rich in various sources of macro and micro minerals. Réhault-Godbert et al. (2019) reported that ash contents in yolk and albumen were 3.7% and 3.4% on DM basis, respectively.

While fat and protein contents did not differ significantly across treatments, the organic eggs showed the highest yolk ash content (2.4%), and conventional eggs had the lowest (1.8%), potentially reflecting differences in mineral absorption and feed sources. The observed higher protein content in albumen compared to previously published values (Réhault-Godbert et al., 2019) may reflect advancements in feeding strategies. The distribution of ash content in yolks is summarized in Table 4, indicating that organic eggs have a wider range and higher values compared to conventional and omega-3 eggs. The non-significant differences observed in certain chemical parameters between egg types and grades could be attributed to standardized feeding practices and similar production conditions across farms. Additionally,

nutrient content may be less affected by external grading factors compared to physical traits.

This study was limited by the unavailability of grade C samples for organic and omega-3 rich eggs, which had reduced the completeness of cross-grade comparisons. Moreover, sourcing eggs from local grocery stores introduces potential variability due to differences in handling and supply chain conditions, which could influence freshness and quality attributes. Future studies should consider functional nutritional assessments (e.g., antioxidant content, cholesterol oxidation), consumer preference surveys, and shelf-life evaluations under different storage conditions. A larger and more controlled sample base across certified sources could further validate the present findings.

4. CONCLUSION

Statistically significant differences were noted in egg weight, albumen height, yolk height, shell thickness, yolk index and HU values among different egg types and grades. However, no significant differences in the above-mentioned parameters were found among treatments, regardless of egg type or egg grade. Omega-3 rich eggs showed comparatively higher values for specific traits, namely egg weight, albumen height, yolk height, yolk index and HU value, compared to organic and conventional eggs. This advantage was limited to these specific physical quality traits and did not extend to shell thickness, which was higher in conventional eggs. From a nutritional perspective, organic eggs showed the highest ash content (2.4%), which may reflect a higher mineral content potentially associated with organic feed formulations that commonly include mineral-rich components such as seaweed, or organically approved mineral supplements. For physical quality, consumers may find that omega-3 rich eggs may be preferable when selecting better physical quality selection, such as freshness and internal quality, while organic eggs may be favoured for their potentially higher mineral content. These findings contribute to the quality standards and enhance market transparency by providing evidence-based comparisons of egg quality traits across types and grades. Stakeholders should consider including mineral composition in egg labeling and pricing strategies to better inform consumer choice, particularly for health-conscious or nutritionally motivated buyers. However, the justification for the higher cost of organic eggs would depend on individual consumer priorities, whether they value enhanced mineral composition or other factors such as production method, animal welfare, or perceived health benefits.

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AUTHOR'S CONTRIBUTIONS

Mohammad Mijanur Rahman: Conception and design of the study, critical review of the manuscript; Nurathirah A Rahman: Field experiments, data acquisition, data tabulation, data analysis and interpretation, and manuscript preparation and revision; Renny Fatmyah Utamy: Conception and design of the study, critical review of the manuscript; Md. Safiul Alam Bhuiyan: Critical review of the manuscript; Mohamad Asrol Kalam: Data analysis and interpretation.

CONFLICT OF INTEREST

The authors would like to state that there are no conflicts of interest regarding the material discussed in this manuscript.

REFERENCES

- Albader, N. A., Arzoo, S., Nouri, D. M. A., Binobead, M. A., Alfayez, F. F. (2024). Study on the egg components and fatty acid composition of organic egg and commercially available table eggs obtained from different establishments commonly consumed in Riyadh. *International Journal of Biosciences*, 25(2), 172-179. <http://dx.doi.org/10.12692/ijb/25.2.172-179>
- Alkan, S., Türker, İ. (2021). Effects of egg shape index on egg quality in Partridges. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi*, 11(2), 140-151. <https://doi.org/10.54370/ordubtd.996530>
- Altunalmaz, S. S., Aksu, F., Bala, D. A., Akyazi, İ., Çelik, C. (2020). Evaluation of quality parameters of chicken eggs stored at different temperatures. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, 26(2), 247-254. DOI: 10.9775/kvfd.2019.22856
- An, J.H., Hwang, Y., Hwang, S., Kwon, H., Gu, H., Park, K., Choi, C., (2023). Comparative evaluation of egg quality in response to temperature variability: from farm to table exposure scenarios. *Food Science of Animal Resources*, 43(6), 1002-1016. DOI: 10.5851/kosfa.2023.e62
- AOAC International (2012). *Official Methods of Analysis*. 19th edition. USA.
- Cicek, T., Kartalkanat, A. (2009). Comparison of village eggs and commercial eggs in terms of egg quality. *Journal of Animal and Veterinary Advances*, 8(12), 2542-2545.
- DSM Nutritional Products Ltd. (2022). *DSM egg quality manual*. Retrieved from <https://www.dsm.com/content/dam/dsm/anh/en/documents/dsm-egg-quality-manual.pdf>
- Duman, M., Şekeroğlu, A., Yıldırım, A., Eleroğlu, H., Camcı, Ö. (2016). Relation between egg shape index and egg quality characteristics. *European Poultry Science*, 80(3), 1-9. DOI: 10.1399/eps.2016.117
- Filipiak-Florkiewicz, A., Dymińska-Czyż, M., Szymczyk, B., Franczyk-Żarów, M., Kostogryś, R., Florkiewicz, A., Lukasiwicz, M. (2024). Design of physicochemical properties of eggs as a result of modification of the fat fraction of laying feed. *Molecules*, 29(6), 1242. DOI: 10.3390/molecules29061242
- Hammershøj, M., Kristiansen, G.H., Steinfeldt, S. (2022). Correction: Hammershøj et al. Dual-purpose poultry in organic egg production and effects on egg quality parameters. *Foods* 2021, 10, 897. *Foods*, 11(3), 311. DOI: 10.3390/foods11030311
- Harms, R.H. (1990). Specific gravity of eggs and eggshell weight from commercial layers and broiler breeders in relation to time of oviposition. *Poultry Science*, 70, 1099-1104.
- Harnsoongnoen S., Jaroensuk N. (2021). The grades and freshness assessment of eggs based on density detection using machine vision and weighing sensor. *Scientific Reports*, 11(1), 16640. DOI: 10.1038/s41598-021-96140-x
- Hejdysz, M., Nowaczewski, S., Perz, K. et al. (2024). Influence of the genotype of the hen (*Gallus gallus domesticus*) on main parameters of egg quality, chemical composition of the eggs under uniform environmental conditions. *Poult. Sci.* 103(1), 103165. DOI: 10.1016/j.psj.2023.103165
- Hisasaga, C., Griffin, S. E., Tarrant, K. J. (2020). Survey of egg quality in commercially available table eggs. *Poultry Science* 99(12), 7202-7206. DOI: 10.1016/j.psj.2020.09.049
- Jiang, M. J., Zhao, J. P., Jiao, H. C., Wang, X. J., Zhang, Q., Lin, H. (2015). Dietary supplementation with sodium bicarbonate improves calcium absorption and eggshell quality of laying hens during peak production. *British Poultry Science*, 56(6), 740-747. DOI: 10.1080/00071668.2015.1113499

- Kim, Y. B., Lee, S. Y., Yum, K. H. et al. (2024). Effects of storage temperature and egg washing on egg quality and physicochemical properties. *Discover Applied Sciences*, 6, 111. <https://doi.org/10.1007/s42452-024-05760-1>
- Lee, M. H., Cho, E. J., Choi, E. S., Sohn, S. H. (2016). The effect of storage period and temperature on egg quality in commercial eggs. *Korean Journal of Poultry Science*, 43(1), 31-38. <http://dx.doi.org/10.5536/KJPS.2016.43.1.3131>
- Maina, A. N., Lewis, E., Kiarie, E. G. (2023). Egg production, egg quality, and fatty acids profiles in eggs and tissues in Lohmann LSL lite hens fed algal oils rich in docosahexaenoic acid (DHA). *Poultry Science*, 102, 102921. <https://doi.org/10.1016/j.psj.2023.102921>
- Menezes, P. C. D., Lima, E. R. D., Medeiros, J. P. D., Oliveira, W. N. K. D., Neto, J. E. (2012). Egg quality of laying hens in different conditions of storage, ages and housing densities. *Revista Brasileira de Zootecnia*, 41(9), 2064-2069. <https://doi.org/10.1590/S1516-35982012000900014>
- Nik, M. G., Mahdavi, R., Ghazi, S., Gholami, K. (2024). Efficacy of dietary supplementation with 1 α -hydroxycholecalciferol on performance, eggshell quality, serum metabolites, jejunal morphology and bone characteristics of laying hens at the late stage of production. *Poultry Science*, 104(1), 104618. DOI: 10.1016/j.psj.2024.104618
- Qiu, K., Chang, X., Wang, J., Zhang, H., Wu, S. (2024). Effects of dietary calcium lactate supplementation on laying performance, blood index, shinbone quality, jejunal immunity, and egg quality of aged laying hens. *Agriculture*, 14(2), 256. <https://doi.org/10.3390/agriculture14020256>
- Réhault-Godbert, S., Guyot, N., Nys, Y. (2019). The golden egg: nutritional value, bioactivities, and emerging benefits for human health. *Nutrients*, 11, 684. DOI:10.3390/nu11030684
- Rho, T. G., Cho, B. K. (2024). Non-destructive evaluation of physicochemical properties for egg freshness: A Review. *Agriculture*, 14(11), 2049. <https://doi.org/10.3390/agriculture14112049>
- Romero, C., Yustos, J. L., Sánchez-Román, I., López-Torres, M., Chamorro, S. (2024). Assessment of performance and egg quality in laying hens of Spanish indigenous breed Black Castellana as compared with a selected white egg-layer strain. *Poultry Science*, 103(10), 104096. DOI: 10.1016/j.psj.2024.104096
- Safaa, H. M., Serrano, M. P., Valencia, D. G., Arbe, X., Jiménez-Moreno, E., Lázaro, R., Mateos, G. G. (2008). Effects of the levels of methionine, linoleic acid, and added fat in the diet on productive performance and egg quality of brown laying hens in the late phase of production. *Poultry Science*, 87(8), 1595-1602. <https://doi.org/10.3382/ps.2008-00005>
- Sze, W.K., Huda, N., Dewi, M., Hashim, H. (2018). Physicochemical properties of egg yolk powder from eggs of different types of bird. *Int. J. Adv. Sci. Engin. Inf. Technol.*, 8(2), 384-389. <https://doi.org/10.18517/ijaseit.8.2.4087>
- Tian, Y., Zhu, H., Zhang, L., Chen, H. (2022). Consumer preference for nutritionally fortified eggs and impact of health benefit information. *Foods*, 11, 1145. <https://doi.org/10.3390/foods11081145>
- Tougan, U.P., Thewis, A. (2024). Factors affecting egg quality and functional properties. *International Journal of Advanced Research*, 12(8), 1235-1250. DOI: 10.21474/IJAR01/19366
- Wakchaure, S. (2023). Prevention of Heat Stress in Poultry. *Trouw Nutrition India*. https://www.trouwnutritionasiapacific.com/en-in/7.0-tn-ln-news-and-events/highlighted-stories/2023/mineral-nutrition-dairy2/?utm_source=chatgpt.com (accessed on 15 May 2025)
- Yahaya, H. K., Olutunmogun, A. K., Bolufawi, E. T. (2024). Egg weight, shell thickness and cholesterol concentration in specialized breeds of egg-type chickens as influenced by layer age. *FUDMA Journal of Agriculture and Agricultural Technology*, 9(4), 94-98. <https://doi.org/10.33003/jaat.2023.0904.13>
- Yuan, L., Fu, X., Yang, X., Chen, X., Huang, G., Chen, X., Shi, W., Li, L. (2023). Non-destructive measurement of egg's Haugh Unit by Vis-NIR with iPLS-Lasso selection. *Foods*, 12, 184. <https://doi.org/10.3390/foods12010184>
- Zahira, A., Salleh, S. M. A., Yaakub, H. (2021). Is the information on the egg label claimed by egg producer true? *Malaysian Journal of Animal Science*, 24(2), 59-65.
- Zita, L., Okrouhlá, M., Krunt, O., Kraus, A., Stádník, L., Čítek, J., Stupka, R. (2022). Changes in fatty acids profile, health indices, and physical characteristics of organic eggs from laying hens at the beginning of the first and second laying cycles. *Animals*, 12(1), 125. <https://doi.org/10.3390/ani12010125>