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Evaluating the Internal and External Quality Attributes of Table Eggs from (Local Providers) in the Different Regions of Iraq

Ameen R. Al-Hamadani[1], Omar F. Al-Bajjary[2], Ahmed Husham Hammo[1], Ali M. Saadi[3], Mohammed Al-Juhaishi[4], Harith Al-Mansour[1], Waseem A. Hashem[1]

[1]Therapeutic Nutrition Department, Al-Nimrud Technical Institute, Northern Technical University, Mosul, Iraq
[2]Internal dorm departments, University of Mosul, Iraq
[3]Department of Biotechnology and Food Science, Technical Agricultural College, Northern Technical University, Mosul 41001, Iraq
[4]Department of Animal Production Techniques, Northern Technical University, Mosul, Iraq

***Corresponding author:** E-mail: ali.mohammed@ntu.edu.iq

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Abstract

The aim of this study was to investigate the physical and chemical properties of six egg types from different regions of Iraq. In total, 360 eggs were bought from local markets in the following places: Mosul City (T1), Erbil City (T2), Kirkuk City (T3), Duhok City (T4), Sulaymaniyah City (T5), and Wasit City (T6). The physical dimensions included egg weight, egg shape, eggshell thickness, and albumen and yolk properties. Quality indices such as shape index, yolk index, and Haugh unit were calculated using standard formulas. There was a significant difference between the types ($P \leq 0.05$). The egg weight (71.92 g), thick albumen height (7.11 mm), and Haugh unit (80.65) were highest for T5, indicating superior quality. T4 sample had the lowest yolk index (0.266) and Haugh unit (50.59) among all samples. There is a significant difference in quality among various areas in the available Table Eggs in Iraq. Of the 60 eggshells that were tested, 50% of them were found to be contaminated with microbes. The positive samples were 66.6% bacteria (*Staphylococcus epidermidis* and *Staphylococcus aureus*), and 33.3% fungi (*Aspergillus* spp.).

Keywords: Egg quality, Haugh unit, Shape index, Yolk index, Bacteria of eggshell.

Introduction

Chicken eggs are one of the most economically important and nutritionally valuable food products in the world, containing high-quality protein, essential amino acids, vitamins, and minerals at low cost (1, 2). Over the past few decades, the egg industry has experienced tremendous growth worldwide, as consumers have become more demanding of both quality and safety of table eggs (3). Egg quality includes both external and internal attributes, including the integrity, cleanliness, and shape of the shell, as well as the weight of the albumen, yolk colour, and the Haugh Unit, which are all factors that impact consumer acceptance, marketability, and economic value (4, 5).

The quality of an egg does not stay the same but changes over time, influenced by many factors including the hen's age and breed, feed, production system, storage and time since laid (6, 7). Of these, storage temperature and length are especially significant because eggs are dynamic living biological systems which continue to change biochemically and physically after they are laid (8).

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Moisture loss and carbon dioxide loss from the porous eggshell cause an increase in the size of air cells, an increase in pH of albumen and yolk, a decrease in albumen height, weakening of the vitelline membrane, and a general decrease in the freshness indicators like Haugh unit and yolk index in stored eggs (9- 11).

In 1937, the Haugh unit was invented by Raymond Haugh, which is the most commonly used objective assessment of internal egg quality, and involves multiplying egg weight by thick albumen height (12). Good eggs have a Haugh unit value greater than 72, and old eggs have a Haugh unit value less than 60 (13, 14). In the same way, the height of the yolk relative to its diameter (yolk index) and the length of the albumen relative to the diameter of the yolk (albumen index) are useful indicators of egg freshness, with higher indices being better indicators of younger egg production (15, 16).

Eggs can spend several days in production facilities and days in transit before reaching the retail outlet, where they could be improperly stored and exposed to temperature extremes, poor storage conditions and/or longer storage times (17, 18). Ambient temperature storage is used in developing countries and areas where the cold chain is not well established, which can cause deterioration of the quality (19, 20). There have been several recent studies that have reported important differences in the quality of local eggs from different markets, which could be due to differences in how the eggs are produced, sheep genetics, feed formulation, egg handling, or the time between egg production and retail sale (21- 23).

In recent years, the poultry sector has had a remarkable development in Iraq, especially in the Kurdistan Region and Mosul City, where a number of local egg production facilities have been established to meet the local demand (24). There are limited scientific studies of the quality attributes of eggs locally available in this region. The effect of storage conditions on egg quality in Middle East markets, due to the high temperature and humidity changes, has been demonstrated (25, 26). Lack of standardised quality control measures and cold chain management in many retail outlets is a concern for the uniformity and safety of eggs reaching consumers (27).

The knowledge of the normal quality characteristics of eggs from different local types and the rate of decline in quality during normal storage periods are necessary for many reasons. The assessment then helps to determine areas of the egg industry in the region that may have potential for improvement in production, handling, and distribution practices (28,29) so that consumers and retailers can make informed buying decisions and make stocking decisions. It also provides a baseline of information for future quality monitoring and regulatory efforts (30).

The egg shell provides primary physical protection of the internal egg contents but is permeable making it easy to contaminate the surface and potentially be invaded by pathogens such as Salmonella spp. and *Escherichia coli*. The inspection of the eggshells' microbiome is therefore an essential part of food safety measures and public health threat assessments. Total microbial counts and identification of bacterial and fungal contaminants give important clues about the efficiency of sanitary measures adopted in poultry farms and processing units. These microbiological assessments are setting critical quality standards that are essential to reduce foodborne diseases and product risk to human health (31,32).

No previous reports of extensive comparative studies have been reported to determine the importance of several locally available market eggs. This lack of knowledge makes it challenging for these stakeholders to make decisions as well as implement evidence-based quality improvement activities.

The aims of this study were: (1) to analyze and compare the physical and chemical characteristics of six important egg types of the area, emphasizing the measurements of weight, dimensions, thickness of the shell, characteristics of the albumen and yolk, and quality indexes; (2) to evaluate the microbial load and bacterial diversity on the egg surface and to assess the effectiveness of the current sanitary procedures; and (3) to provide basic data and recommendations for improving quality in the local egg sector.

Material and Methodes

Egg sample and location

This study was carried out at the Technical Institute of Nimrud / Northern Technical University – Mosul, Iraq, from October 2025 until January 2026. Six types of eggs were selected systematically for inclusion in the study according to their availability in the market from various local areas in Iraq. A total of 360 fresh eggs (60 eggs per brand) were bought directly from local retail markets. The six types and their production are given in Table 1.

Table 1. Local egg types evaluated in the study

Types	Production Location	Production Date
T1	Mosul City	9/10/2025
T2	Erbil City	13/10/2025
T3	Kirkuk City	10/10/2025
T4	Duhok City	11/10/2025
T5	Sulaymaniyah City	13/10/2025
T6	Wasit City	12/10/2025

After purchase, the samples were carefully transported to the laboratory under controlled environmental conditions to ensure the integrity of the samples and stability of the microbial profile, prior to the experimental analysis.

Equipment and Measurement

Measurements of a physical nature were carried out using calibrated precision instruments. Eggs were weighed using a digital balance with a 0.01 g precision. The maximum length of the egg (longitudinal axis) and maximum width of the egg (transverse axis) were measured using an Electronic Vernier Caliper, which has an accuracy of 0.01 mm.

The internal quality assessment of eggs was done by carefully breaking the eggs onto a flat glass surface. The middle thickness of the albumen between the yolk and the outer edge was taken using an Electronic Vernier Caliper. Yolk diameter was measured at the widest diameter, and yolk height was measured at the highest point of the yolk with the same caliper. The Yolk Color Fan is a standardised colourimetric device that measures the colour of the yolk on a scale of 1 (pale yellow) to 15 (dark orange).

The albumen and yolk were then weighed individually on a digital balance. Using the Electronic Vernier Caliper, the thickness of the shell was measured at three different positions (broad end, middle, and pointed end), and the average thickness was calculated.

Quality Indices Calculation

Several quality indices were computed with the use of known formulas that will give a comprehensive evaluation of egg quality:

Shape Index (%) was computed using the method of Duman et al., 2016, which was given as:

Shape Index (%) = (Egg Width / Egg Length) × 100 [28]

Egg shape is normal or ideal if 72-76%, elongated if below 72%, and rounded if above 76% shape index value.

Yolk index was determined by yolk height/yolk diameter:

The Yolk Index is the ratio of the height of the yolk to the diameter of the yolk in mm (33).

Eggs with a yolk index > 0.38 can be defined as fresh and good quality, > 0.30 as medium, and < 0.30 as weak and old egg.

Haugh Unit (HU) was computed based on the following formula suggested by Haugh (1937):

$HU = 100 \times \log_{10}(H + 7.57 - 1.7 W0.37)$ (34).

Thick albumen height (mm) is H and egg weight (g) is W. The Haugh unit is considered to be the most widely accepted indicator of internal egg quality, with a higher score indicating more excellent internal quality; thus, scores above 72 denote AA grade (excellent quality), scores between 60 and 72 denote A grade (good quality), scores between 31 and 60 denote B grade (acceptable quality), and scores below 31 denote poor quality.

Sixty samples of eggs were taken from their surface with sterile swabs and then inoculated onto blood agar and MacConkey's agar and incubated for 24 hours at 37 degrees Celsius. The isolates were first characterized according to the growth characteristics and macroscopic appearance, and then examined under the microscope after applying Gram's stain (with 99% ethanol in the decolorization step) using crystal violet, iodine, and safranin. In order to help identify the organism, biochemical tests like oxidase and catalase tests were performed. The Vitek 2 compact system was used to confirm the species of bacteria with the objective of gaining accuracy. Throughout the procedures, solutions such as 0.9% normal saline were utilized to prepare and handle the samples. A comprehensive approach was developed by combining traditional microbiological methods with automated technology to accurately identify the isolated microorganisms.

Statical Analysis

Data from the completely randomized design were evaluated using a one-way analysis of variance. Duncan's multiple range test was applied at a significance threshold of, in accordance with the established protocol of Duncan (35), to identify significant differences among treatment means.$p \leq 0.05$, All statistical computations were performed using the SAS software package in accordance with the experiment's specified mathematical model. Significant differences are indicated by different letters within the same column, with results presented as mean ± standard error (SE), at a significance level of $P < 0.05$, in accordance with the specific mathematical model used for the analysis.

$Y_{ij} = u + t_i + E_{ij}$

Were:

Y_{ij} = the observation of ij.

μ = the overall mean.

T_i = the effect of i (types).

E_{ij} = the random error.

Results and Discussion

Effect of Types on Physical Egg Characteristics

Physical measurements of eggs from the six local types are presented in Table 2. Egg weight differed significantly among types ($P \leq 0.05$), ranging from 59.02 g (T6) to 71.92 g (T5). Sulaymaniyah city (T5) produced significantly heavier eggs than all other types, while Wasit city (T6) had the lightest eggs. The weight of eggs is one of the most important factors for local value and choice; larger eggs are likely to fetch a high price in the market.

Table 2. The effect of egg types on egg weight, shape index, albumen weight, thick albumen height and haugh unit (Mean ± Standard Error)

Types	Egg Weight (g)	Shape Index (%)	Albumen Weight (g)	Thick Albumen Height (mm)
Type 1	66.51 ± 3.53 ab	73.29 ± 1.24 b	39.14 ± 2.89 ab	3.83 ± 0.29 d
Type 2	66.25 ± 0.81 ab	77.30 ± 0.97 a	39.39 ± 1.13 ab	6.13 ± 0.15 b
Type 3	62.66 ± 0.62 bc	74.91 ± 1.30 ab	35.80 ± 0.40 b	5.35 ± 0.24 c
Type 4	64.52 ± 1.88 bc	74.74 ± 1.27 ab	35.71 ± 1.47 b	3.59 ± 0.18 d
Type 5	71.92 ± 1.75 a	77.27 ± 1.02 a	41.50 ± 1.66 a	7.11 ± 0.16 a
Type 6	59.02 ± 1.48 c	75.95 ± 0.54 ab	35.91 ± 1.58 b	5.21 ± 0.28 c

a-d The different superscript letters in the same column show significant differences ($P \leq 0.05$).

The weight variation in eggs among types observed may be due to several factors: hen genetics, age of the laying flock, nutritional management, and production system (1, 5). Recent studies have shown that egg weight is largely affected by the hen strain, and the high-production modern local hens produce eggs in the size of 60–65 g, whereas the specialized strains produce larger eggs (6, 10). The weight of T5 eggs is significantly heavier and may be due to one or more of the following factors: a different genetic line, older hens (as hens age, the eggs grow heavier), or better nutritional management than other types.

Egg quality indices are comprehensive measures of egg quality and are widely used for egg grading and egg quality evaluation (Table 2). The shape index ranged from 73.29% (T1) to 77.30% (T2), and the eggs of T2 showed significantly more rounded eggs than T1 and T4. Egg shape is classified according to the shape index (SI), which ranges from 80 to 45, and eggs with an index of 72-76% are considered to have a normal or ideal shape, while eggs with a shape index more than 76% are more rounded (28). The majority of the types in this study were within or close to the normal range, with a few having highly rounded eggs, such as T2 and T5. The shape of an egg is largely determined by genetic determination and the anatomy of the hen's oviduct and remains relatively stable after storage (22,29).

The weight of albumen ranged from 35.71g (T6) to 41.50g (T5), and among the different types, T5 has a significantly ($P<0.05$) higher amount of albumen than other types. The higher elevation found for treatment T5 is mainly attributed to the significant rise in the overall egg weight, which means that more dense albumen was found in heavier eggs. The albumen weight is the most abundant weight fraction of the egg and plays an important role in the nutritional and functional properties of the egg in food applications (2, 11).

The thickness of the albumen is one important factor for the freshness and quality of the egg; it will thin rapidly over time during storage because the ovomucin-lysozyme complex, which lends albumen gel its thickness, breaks down during storage (8, 11). Significant differences between the types were found, where T5 had the greatest thick albumen height (7.11 mm), followed by T2 (6.13 mm), T3 (5.35 mm), T6 (5.21 mm), T1 (3.83 mm), and T4 (3.59 mm). The higher the thick albumen height is, the fresher the eggs are or the better the handling from production to retail, and the lower the thick albumen height, the older the eggs are or the poorer the handling between production and retail (13,15).

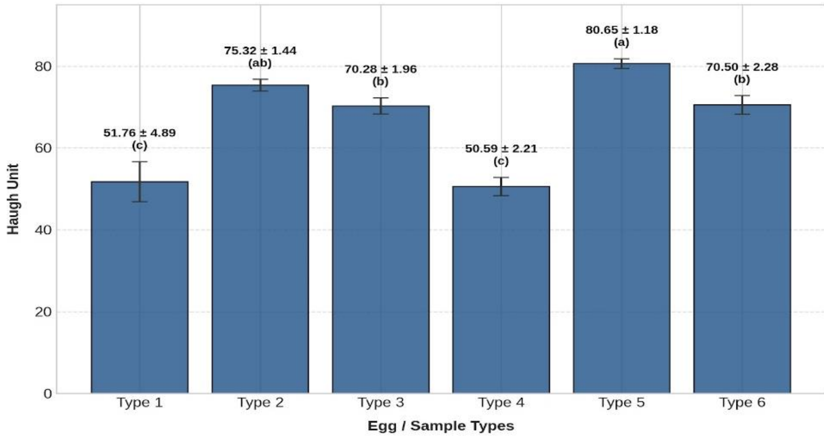

Figure 1: Haugh unit comparison across types (Mean ± SD)

The Haugh unit, which is the most commonly used internal egg quality measurement, exhibited significant differences among the different types of eggs, from 50.59 (T4) to 80.65 (T5). According to USDA grading standards, T5 eggs (HU = 80.65) and T2 (HU = 75.32) qualify as AA grade (excellent quality, HU >72), T3 and T6 eggs (HU = 70.28 and 70.50, respectively) qualify as A grade (good quality, HU 60–72), while T1 and T4 eggs (HU = 51.76 and 50.59) fall into B grade (acceptable to poor quality, HU 31–60) (1,4). The high Haugh unit values obtained from T5 eggs are due to the high thick albumen height and the appropriate egg weight, which are indicators of the excellent freshness and handling practices of these eggs (10, 14). The low value of the Haugh unit in T4 eggs (50.59) shows a lower egg quality, which is probably related to longer storage time or sub-optimal storage conditions (18, 25).

Recent research examining the quality of local eggs in different markets has yielded similar findings. In fresh eggs, Haugh unit values between 60 and 98 were reported by (1) who found that the eggs significantly deteriorated during storage (5), identified significant differences in the quality of local egg types in the Croatian market, representing of Haugh units from 65 to 85 [5,13], and colleagues reported on the same variations in egg quality across markets in Saudi Arabia, emphasizing the importance of cold chain management and the need for rapid product rotation to ensure egg quality (14,30), showed that the storage time has significant influence on the Haugh unit values and that the effect was increased in higher temperatures (30).

Yolk characteristics varied significantly among the six types (Table 3). Yolk weight varied from 15.47 g (T6) to 21.02 g (T5), with T5 and T4 having significantly heavier yolks than other types. Yolk weight is relatively stable during storage and is primarily determined by hen genetics, age, and nutrition (7, 10). The heavier yolks in T5 are consistent with the overall larger egg size from this brand. The lighter yolks in T6 correspond to the smaller overall egg size from this brand.

Yolk index showed substantial variation among types, ranging from 0.266 (T4) to 0.414 (T5). T2, T5, and T6 had the highest yolk index values (0.402,0.414, and 0.400, respectively), indicating fresh, high-quality eggs (>0.38), while T4 had an extremely low yolk index (0.266), well below the threshold for acceptable quality (<0.30), indicating weak or old eggs (9, 12). T1 and T3 had intermediate values in the medium quality range (0.30–0.37). The very poor yolk index in T4 eggs, despite being within their stated shelf life, raises concerns about storage conditions (16, 23).

The color of the yolk differed greatly between types, ranging from 5.00 (T6) to 14.00 (T2). The yolk colour of eggs produced by the T2 breed was found to be significantly darker than all other breeds followed by T3 (11.00) and T4 (10.6) while the eggs of T1 and T6 showed the palest yolk colour. The main methods of achieving yolk colour are to increase the concentration of carotenoids (especially xanthophylls) in the hen's feed, and yellow yolk colour is generally preferred in many markets (3, 7). The diversity in yolk color between types indicates significant differences in the types of feed formulation and the use of natural colour ingredients such as corn, alfalfa, or synthetic carotenoids (15,21).

Table 3 shows the characteristics of eggshells. The weight of the shell ranged from 7.63 g in T6 to 9.40 g in T5; the latter species had a significantly heavier shell than the others. The weight of eggshells is directly proportional to the overall egg weight as well as the thickness of the shell, and this will impact the protection of the egg during handling and transport (4,13).

Average Shell thickness at the broad end, middle, and pointed end showed relatively less variation among types than other parameters. However, there were significant differences, where T6 had the thickest shell (0.538 mm), significantly greater than T2 (0.476 mm). Shell thickness is influenced by hen genetics, age, calcium and vitamin D nutrition, and environmental stress (6,13). Adequate shell thickness (typically >0.35 mm) is essential for protecting egg contents during handling, transportation, and storage and for preventing microbial contamination (14,19).

Research has demonstrated that the thickness of the shell may vary significantly depending on the source of the egg, from 0.30 to 0.55 mm (20, 26). The shell thickness values measured in this study are typical and comparable to those found in local laying hens. This is because thicker shells in T5 are believed to provide better protection and may lead to less deterioration in shell quality in storage (27, 30).

Table 3. Effect of egg types on yolk characteristics, shell weight, and average shell thickness (Mean ± SE).

Types	Yolk Weight (g)	Yolk Index	Yolk Color	Shell Weight (g)	Average Shell Thickness (mm)
Type 1	19.04 ± 0.83 a	0.318 ± 0.007 c	6.0 ± 0.0 e	8.31 ± 0.19 b	0.483 ± 0.008 b
Type 2	18.69 ± 0.67 a	0.402 ± 0.005 a	14.0 ± 0.0 a	8.16 ± 0.06 b	0.476 ± 0.012 b
Type 3	18.85 ± 0.60 a	0.364 ± 0.008 b	11.0 ± 0.0 b	8.00 ± 0.29 b	0.487 ± 0.011 b
Type 4	21.01 ± 0.74 a	0.266 ± 0.007 d	10.6 ± 0.24 c	7.79 ± 0.26 b	0.500 ± 0.014 b
Type 5	21.02 ± 1.02 a	0.414 ± 0.010 a	10.0 ± 0.0 d	9.40 ± 0.31 a	0.501 ± 0.009 b
Type 6	15.47 ± 0.74 b	0.400 ± 0.011 a	5.0 ± 0.0 f	7.63 ± 0.11 b	0.538 ± 0.015 a

a-f Different superscript letters within the same column indicate significant differences (P≤0.05).

The identification of Egg Surface Microbiota.

1- Sample culturing

There were 50% (30 out of 30) that were negative for any growth after incubation and 50% (30 out of 30) of samples were positive.

2- Identification

Results from observation of the positive samples under the microscope and biochemical testing showed that 66.6% (20) of the samples had bacterial growth while 33.3% (10) had fungal growth, as shown in Figure 2.

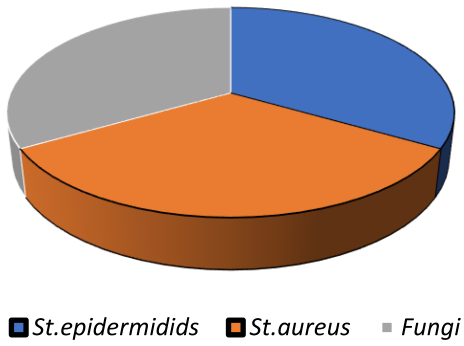

Figure 2 shows the percentage of bacteria and fungi obtained from the samples.

One sample showed growth of *Staphylococcus epidermidis* (Figure 3), another sample has shown growth of *Staphylococcus* aureus (Figure 4), and the other sample showed growth of fungi (Figure 5).

Figure 3: *St.epidermidis* on blood agar

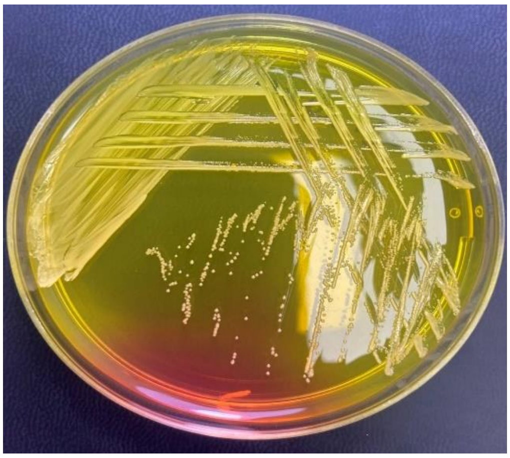

Figure 4: *St.aureus* on mannitol salt agar

Figure 5: Fungi on blood agar

In the present study, it was found that 50% of examined eggshells were overall contaminated with microbes. This moderate to high level of environmental exposure and post-egg-laying contamination, as reflected by recent studies, ranges from 40% to 65% of microbial prevalence on eggshells, depending on housing systems, hygiene measures, and handling conditions at retail outlets (36). The bacterial prevalence ratio (66.6%) to fungal (33.3%) is consistent with the known microbiological patterns, as bacteria are known to colonise organic substrates and are fast to adapt to the minute changes in the environment on the eggshell surface.

All the observed bacteria (50%) were Staphylococcus epidermidis, and Staphylococcus aureus (50%). The presence of Staphylococcus suggests that humans and animals are involved in egg collection, sorting, and egg packaging. Human handling is a common source of transfer of S. epidermidis, a dominant human symbiont, to the surface of shells (3). On the other hand, isolation of S. aureus is a direct public health issue since this bacterium is known to be a pathogen that can produce enterotoxins that can lead to outbreaks of foodborne illness. This is the issue that was highlighted by the studies conducted by (38,39), which have shown that Staphylococcus spp. are significant contaminants on table eggs, and that there is a link between poor hand hygiene among farm workers and retailers.

All the fungal isolates were identified as Aspergillus species (Aspergillus spp.). Aspergillus is a fungus that is found very frequently in the environment, especially in the air over farms, in poultry litter and feed (40). The absolute dominance suggests that there is considerable dust deposited in the atmosphere during storage and display. This finding is also consistent with a recent study by Ebani et al. (2022) which identified the dominant fungal genus on table eggshells in an open retail environment as Aspergillus (41). The dual hazard of the presence of Aspergillus is that, under the proper moisture conditions, the fungal hyphae can penetrate through the eggshell pores and cause internal damage. This genus contains many species with hazardous mycotoxins such as aflatoxins that pose a risk to food safety (42).

The geographical distribution of these isolates highlights the urgent need for improving post-harvest hygiene practices, adopting automated processing systems, and establishing storage temperature control to reduce microbial risk.

Conclusion

A comparative study was carried out to assess the physical and chemical characteristics of the locally produced Table Eggs in different areas in Iraq. Sulaymaniyah city (T5) had the best egg quality for several measurements, such as egg weight (71.92 g), albumen height (7.11 mm), yolk index (0.414), and Haugh unit (80.65), suggesting AA grade eggs. The quality of samples was very poor in Duhok city (T4), with extremely low value of yolk index (0.266), Thick Albumen Height (3.59) and Haugh unit (50.59) which means the samples had very poor freshness, even within the prescribed shelf life.

The wide range of quality of eggs in the market highlights the need for better quality control systems, better cold chain facilities and consumer education about indicators of egg quality and the proper storage techniques. Producers and retailers should have a sound quality monitoring programme in place, provide good refrigeration along the distribution chain, and reduce the time between production and retail sale. Future research should focus on the specifics of the causes of quality differences between types, which include hen genetics, nutrition, production systems, and post-production handling practices, and the effectiveness of interventions to improve egg quality in the regional market.

The research revealed that 50% of the eggshell samples had microbial contamination with mostly

Staphylococcus species and Aspergillus fungi. The distribution underlines the importance of handling practices and environmental contamination, and stresses food safety concerns, particularly related to the pathogenic properties of S. aureus and the mycotoxin-producing potential of *Aspergillus*. Improving storage conditions and strengthening hygiene measures are crucial to decrease microbial risks linked to table eggs.

Conflict of interest: NIL

Funding: NIL

Reference

1. Ikusika, O. O., Mpendulo, C. T., & Zindove, T. J. (2025). Assessment of Egg Quality Across Seasons, Storage Durations, and Temperatures in Local Laying Hens. *Applied Sciences*, 15(19), 10344. https://doi.org/10.3390/app151910344
2. Madrigal-Portilla, K., Vargas-Leitón, B., & Solano-Soley, M. (2023). Efecto de temperatura y tiempo de almacenamiento sobre la calidad del huevo de gallinas. *Agronomía Mesoamericana*, 34(2), 51223. https://doi.org/10.15517/am.v34i2.51223
3. Lokaewmanee, K., Yamauchi, K., & Komori, T. (2015). Effects of Storage Time on External and Internal Characteristics of Lutein Enriched Eggs. *Journal of Agricultural Science and Technology: B*, 5(9), 589-597. https://doi.org/10.17265/2161-6264/2015.09.007
4. Renukadevi, S., Kannaki, T. R., Haunshi, S., & Verma, P. C. (2018). Quality and shell integrity of Japanese quail eggs: an assessment during storage and at market. *Sri Lankan Journal of Food and Agriculture*, 4(1), 23-30. https://doi.org/10.4038/SLJFA.V4I1.55
5. Kralik, G., Kralik, Z., Grcevic, M., & Hanžek, D. (2017). Quality of table eggs on the Croatian market. *Poljoprivreda*, 23(1), 71-77. https://doi.org/10.18047/POLJO.23.1.10
6. Cozzolino, D., Renna, M., Lussiana, C., Malfatto, V., Battaglini, L. M., & Cornale, P. (2024). Implications of the storage conditions and production system on the physical properties of eggs: a multivariate data analysis study. *International Journal of Food Science & Technology*, 59(5), e17069. https://doi.org/10.1111/ijfs.17069
7. Oliveira, M. C., Silva, V. K., Lana, A. M. Q., Lana, S. R. V., & Lana, G. R. Q. (2020). Bee pollen improves productivity of laying Japanese quails. *Revista Brasileira de Saúde e Produção Animal*, 21, e2121352020. https://doi.org/10.1590/S1519-99402121352020
8. Silva, J. D. T., Lana, S. R. V., Lana, G. R. Q., Lana, Â. M. Q., Cunha, F. S. A., & Marinho, A. L. (2024). Qualidade de ovos de poedeiras comerciais armazenados em diferentes temperaturas e períodos. *Archivos Latinoamericanos de Producción Animal*, 32(Supl. 2), 13-22. https://doi.org/10.53588/alpa.3202002
9. Avcılar, T., Kaya, H., Macit, M., & Çelebi, Ş. (2023). Effects of ultraviolet and ultrasound treatments applied before the storage period on egg quality characteristics. *International Journal of Agriculture, Environment and Food Sciences*, 7(1), 207-216. https://doi.org/10.31015/jaefs.2023.1.25
10. Marzec, A., Damaziak, K., Kowalska, H., Riedel, J., Michalczuk, M., Koczywas, E., Cisneros, F., Lenart, A., & Niemiec, J. (2019). Effect of Hens Age and Storage Time on Functional and Physiochemical Properties of Eggs. *Journal of Applied Poultry Research*, 28(2), 290-300. https://doi.org/10.3382/JAPR/PFY069
11. Adriaensen, I., Gantois, N., Lammens, A., Maertens, B., Huyghebaert, G., Delezie, E., Gussem, M. D., Maes, D., & Aerts, J. (2022).

How Egg Storage Duration Prior to Incubation Impairs Egg Quality and Chicken Embryonic Development: Contribution of Imaging Technologies. *Frontiers in Physiology*, 13, 902154. https://doi.org/10.3389/fphys.2022.902154

12. Kocetkovs, V., Muizniece-Brasava, S., Dukulis, I., & Krastina, V. (2022). The Impact of Eggshell Thickness on the Qualitative Characteristics of Stored Eggs Produced by Three Breeds of Laying Hens of the Cage and Cage-Free Housed Systems. *Applied Sciences*, 12(22), 11539. https://doi.org/10.3390/app122211539

13. Alshaikhi, A., Corzo, A., & Shim, M. Y. (2021). Effects of Storage Period, Marketing Channels and Season on Internal and External Quality of Local Table Eggs Marketed in Riyadh City (Saudi Arabia). *Brazilian Journal of Poultry Science*, 23(3), eRBCA-2020-1334. https://doi.org/10.1590/1806-9061-2020-1334

14. Díaz, C. A., Rodríguez, L. C., & Melo, L. M. (2024). Evaluación de la calidad interna, externa y vida útil del huevo comercial en condiciones de trópico. *Spei Domus*, 19(39), 45-58. https://doi.org/10.16925/2382-4247.2023.02.05

15. Aboonajmi, M., Jahangiri, M., & Hassan-Beygi, S. R. (2018). An Ultrasound Based Technique for the Determination of Poultry Egg Quality. *Research in Agricultural Engineering*, 56(3), 99-105. https://doi.org/10.17221/18/2009-RAE

16. Mendonça, M. O., Sakomura, N. K., Reis, M. P., Viana, G. S., Fernandes, J. B. K., & Hauschild, L. (2024). Qualidade de ovos de poedeiras comerciais de diferentes idades sob distintas temperaturas e períodos de armazenamento. *Arquivos de Ciências Veterinárias e Zoologia da UNIPAR*, 28(2), 1-15. https://doi.org/10.25110/arqvet.v28i2.2024-11483

17. Dutra, D. R., Oliveira, D. D., Rodrigues, E. A., Vaz, D. P., Bertechini, A. G., & Oliveira, B. L. (2021). Qualidade dos ovos frescos e armazenados em função do tempo de permanência nos ninhos em sistema cage-free. *Research, Society and Development*, 10(2), e11810211881. https://doi.org/10.33448/RSD-V10I2.11881

18. Lacerda, M. J. R., Soares, N. M., Bastos, L. P. F., Oliveira, D. D., Lara, L. J. C., Teixeira, M. P. F., Cançado, S. V., & Baião, N. C. (2018). PHYSICAL AND MICROBIOLOGICAL QUALITY OF OPAQUE, SANITIZED, AND CHILLED QUAIL EGGS EXPERIMENTALLY CONTAMINATED WITH Salmonella enteric SER. TYPHIMURIUM. *Figshare*. https://doi.org/10.6084/m9.figshare.7506626

19. Quintero, M. F., Cardona, J. A., & Guzmán, L. F. (2022). Physicochemical and morphometric characterization of eggs from emus (Dromaius novaehollandiae). *South African Journal of Animal Science*, 52(1), 56-64. https://doi.org/10.4314/sajas.v52i1.7

20. Sofralık Yumurtalarda Depolama Öncesi Gam Arabik Kaplama Uygulamasının Yumurta Kalitesine Etkileri. (2022). *Kafkas Universitesi Veteriner Fakultesi Dergisi*, 28(3), 315-322. https://doi.org/10.9775/kvfd.2022.27077

21. Santos, M. S. V., Fernandes, E. A., Ramos, A. L. S., Lara, L. J. C., Cardeal, P. C., & Souza, M. R. (2021). Influence of homeopathy on the quality of eggs of quails stored. *Acta Scientiarum. Animal Sciences*, 43(1), e52609. https://doi.org/10.4025/ACTASCIANIMSCI.V43I1.52609

22. Solano-Soley, M., Vargas-Leitón, B., & Madrigal-Portilla, K. (2025). Influencia de la edad del ave y tiempo de almacenamiento sobre las propiedades del huevo de codorniz japonesa.

Nutrición Animal Tropical, 19(1), 1-28. https://doi.org/10.15517/nat.v19i1.63731

23. Lana, S. R. V., Lana, G. R. Q., Salvador, E. L., Lana, A. M. Q., Cunha, F. S. A., & Marinho, A. L. (2018). Quality of eggs from local laying hens stored in different periods of temperature and storage. *Figshare*. https://doi.org/10.6084/m9.figshare.7511882

24. Senanayake, S. A., Ranaweera, K. K. D. S., & Bamunuarachchi, A. Preservation of quality indices of local eggs in different packing materials at control temperature in Sri Lanka. *Journal of Food Science and Technology*.

25. Guedes, C. E. P., Lara, L. J. C., Fernandes, E. A., Martins, N. R. S., Cançado, S. V., & Baião, N. C. (2022). Internal quality of laying hens' local eggs according to storage time, temperature, and packaging. *Figshare*. https://doi.org/10.6084/m9.figshare.20013010

26. Silva, J. D. T., Lana, S. R. V., Lana, G. R. Q., Lana, Â. M. Q., Cunha, F. S. A., & Marinho, A. L. (2020). Effect of storage time and temperature on the quality of Japanese quail eggs. *Brazilian Journal of Animal and Environmental Research*, 77(4), e1489. https://doi.org/10.17523/BIA.2020.V77.E1489

27. Westbrook, L. A. (2016). Enzyme Supplementation of Layer Hen Diets Containing Whole Flaxseed to Increase n-3 Fatty Acids in Chicken Eggs. *Master's Thesis*, University of Saskatchewan.

28. Duman, M., Şekeroğlu, A., Yıldırım, A., Eleroğlu, H., & Camcı, Ö. (2016). Relation between egg shape index and egg quality characteristics. *European Poultry Science*, 80, 1-9.

29. Haugh, R. R. (1937). The Haugh unit for measuring egg quality. *United States Egg and Poultry Magazine*, 43, 552-555.

30. Murshed, H. M., Kumar, S., Singh, A. K., & Pandey, A. K. (2024). A Comparative Study of the Internal and External Quality Characteristics of Table Eggs and the Effect of Storage Periods and Layer Strain on them under Summer Conditions. *Indian Journal of Animal Research*, 58(7), 1065-1070. https://doi.org/10.18805/ijar.bf-1721

31. El Ftouhy, F. Z., Nassik, S., Nacer, S., Kadiri, A., Charrat, N., Attrassi, K., ... & Hmyene, A. (2022). Bacteriological quality of table eggs in Moroccan formal and informal sector. International Journal of Food Science, 2022(1), 6223404.

32. Vale, I. R. R., Oliveira, G. d. S., de Jesus, L. M., de Castro, M. B., McManus, C., & dos Santos, V. M. (2024). Sustainable Bacterial Control of Hatching Eggshells Using Essential Oils. Antibiotics, 13(11), 1025. https://doi.org/10.3390/antibiotics13111025

33. Funk, E. M. (1948). The relation of the yolk index determined in natural position to the yolk index as determined after separating the yolk from the albumen. Poultry Science, 27(3), 376. https://doi.org/10.3382/ps.0270367.

34. Haugh, R. R. (1937). The Haugh unit for measuring egg quality. United States Egg Poultry Magazine, 43(5),552-555; 572-573.

35. Duncan, D.B. (1955). Multiple range and multiple F tests. Biometrics. 11: 1–42. http://dx.doi.org/10.2307/3001478

36. Gole, V. C., Chousalkar, K. K., & Roberts, J. R. (2021). Microflora of eggshell and egg contents in different egg production systems. *Critical Reviews in Food Science and Nutrition*, 61(12), 2012–2025.

37. Sethi, S., Rana, S., & Sharma, M. (2022). Bacterial profile and hygiene indicators of table eggs sold in informal retail outlets. *Journal of Food Protection*, 85(6), 940–947.

38. Kraśniewska, K., Scibisz, I., & Gniewosz, M. (2020). Microbiological quality and safety of table eggs retailed in different sales distribution channels. *Foods*, 9(10), Article 1412.
39. Alharthi, A. S., Al-Ghamdi, A. A., & El-Kott, A. F. (2023). Prevalence and antibiotic resistance profile of bacterial contaminants isolated from table eggshells in local retail markets. *Poultry Science*, 102(4), Article 102521.
40. Melo, F. D., Wunsche, A. L., & Silva, M. L. (2020). Airborne fungal spore concentration in commercial poultry houses and its impact on eggshell contamination. *International Journal of Environmental Research and Public Health*, 17(8), Article 2780.
41. Ebani, V. V., Najar, B., & Bertelloni, F. (2022). Fungal contamination of eggshells and environmental surfaces in poultry farms: Public health implications. *Applied Sciences*, 12(18), Article 9210.
42. Ahmad, A., Khan, M. A., & Riaz, M. (2023). Mycoflora and mycotoxin risk assessment in commercial table eggs: A review. *Journal of Food Safety and Hygiene*, 9(1), 15–27.