Egyptian Journal of Veterinary Sciences

https://ejvs.journals.ekb.eg/

Enhancing Egg Shelf Life and Safety: A Comparative Study of Chitosan and Arabic Gum Coatings under Ambient and Refrigerated Storage

Hanan R. Ghanayem[1], Amal F. Elbanna[1], Mohamed Saleh[2], Gamilat A. Elsaid[3], Eman El Khawaga[3], Arwa H. Nassar[3], Fadel A. Mohammed[4] and Maha S. Abd Elhafeez[5]

[1]*Food Hygiene Department, Animal Health Research Institute, Tanta Branch, ARC, Egypt.*

[2]*References Laboratory for Veterinary Quality Control on Poultry Production, Animal Health Research Institute, ARC, Dokki-Giza, Egypt.*

[3]*Food Hygiene Department, Animal Health Research Institute, Mansoura Branch, ARC, Egypt.*

[4]*Food Hygiene Department, Animal Health Research Institute, Sohag Branch, ARC, Egypt.*

[5]*Pharmacology and Pyrogen Unit, Chemistry, Toxicology, and Feed Deficiency Dep., Animal Health Research Institute, ARC, Dokki-Giza, Egypt.*

Abstract

FRESH hen eggs are highly nutritious but can spoil quickly due to the porous and fragile nature of their shells. This study evaluated the impact of edible coatings and storage temperature on the quality and microbial stability of table eggs over five weeks. Eggs were coated with chitosan or Arabic gum, dried, and stored either at room temperature, RT (25 ± 1 °C), or under refrigeration (4 ± 1 °C). Weekly assessments included microbiological counts, weight loss, yolk index, Haugh unit, and biogenic amines. Results indicated that uncoated eggs stored at room temperature exhibited the highest microbial loads, weight loss, and spoilage indicators. Chitosan coatings significantly inhibited bacterial growth and biogenic amine formation more effectively than Arabic gum. Refrigerated, chitosan-coated eggs displayed superior preservation, with the lowest total and thermoduric bacterial counts (3.79 and 2.69 $\log_{10}$ cfu/g, respectively), minimal weight loss ($1.40 \pm 0.4\%$), and retained yolk and albumen quality. Biogenic amines, including tyramine, putrescine, and cadaverine, were lowest in this group, supporting the effectiveness of combined chitosan coating and cold storage in maintaining egg freshness and safety.

Keywords: Table eggs, Edible coating, Chitosan, Arabic gum, Shelf life, Haugh unit, Biogenic amine.

Introduction

Eggs are essential to the human diet because of their high nutritional value and versatility [1]. Maintaining their quality during storage is critical for consumer health and sensory appeal [2].

Egg quality is determined by an interplay of physical, chemical, biological, and functional characteristics that are significantly influenced by storage conditions, including temperature, humidity, and duration [3]. A notable chemical change during storage is the thinning of albumen. This occurs when carbonic acid (H_2CO_3), an important part of the albumen's buffering system, dissociates into water and carbon dioxide (CO_2), with the CO_2 escaping through the eggshell pores and contributing to quality decline [4,5].

As eggs are stored over time, they experience a decrease in weight and a decline in quality indicators, such as the Haugh unit, albumen index, yolk index, and albumen pH [6]. To mitigate these effects, protective coatings are applied to the eggshell. Various materials have been studied for this purpose, including chitosan [7,8,9], whey protein [9,10,11], molasses [12], propolis [13], and beeswax [14].

*Corresponding author: Maha S. Abd Elhafeez, E-mail: mahasabry86_doctor@hotmail.com, Tel.: +201118433785
(Received 27 June 2025, accepted 26 August 2025)
DOI: 10.21608/ejvs.2025.398387.2928

Arabic Gum has been used as an edible coating directly or in combination with different materials in recent years to extend the shelf life of eggs and vegetables as well as meat products such as meatballs [15,16]**.** Such long-term preservation is possible as the Arabic gum film minimizes contact between the external environment and the coated material.

These coatings help preserve egg quality during storage by limiting water and CO_2 loss, which in turn reduces microbial ingress [17,18]. The Haugh unit (HU), which measures albumen height relative to egg weight, is widely used to assess egg quality because it correlates strongly with visual freshness and reflects storage conditions [19,20].

Egg spoilage is mainly driven by microbial contamination, with factors like humidity, packaging design, ventilation, and temperature playing key roles in maintaining eggs' microbial integrity [21,22,23]. While traditional methods, such as measuring Haugh units, pH, and visual inspection, offer useful insights, they do not fully capture the complex spoilage mechanisms at work in eggs [24]. Furthermore, biogenic amines such as histamine, tyramine, putrescine, and cadaverine are emerging as reliable quality indicators. Fresh eggs contain negligible levels of these compounds, while increased microbial activity during storage at room temperature (approximately 20–25 °C) can lead to significant accumulation, signalling spoilage [25,26,27]. High-performance liquid chromatography (HPLC) is a crucial tool for accurately quantifying these amines and facilitating a nuanced assessment of egg freshness over time [25,28].

This study aims to assess the evolution of biogenic amine levels in eggs stored at room temperature and refrigerator covered with chitosan or Arabic gum. By correlating the chemical data with storage duration, this research seeks to offer a more comprehensive understanding of egg spoilage dynamics, ultimately contributing to improved quality control measures in the egg production and distribution sectors.

Material and Methods

Collection of samples

A total of 450 unfertilized table egg samples, weighing between 55 and 65 grams, were collected from an egg farm in Gharbia, Egypt, during October 2024. The eggs were kept under regulated temperatures and promptly transported to the laboratory with minimal delay for examination. Any eggs with cracked shells or leaks were excluded from the sample. The collected eggs were packed in sterile plastic bags and brought directly to the laboratory for physical, chemical, and microbiological analysis. They were divided into six groups of 75 eggs each (Table 1) to assess different storage periods: on the day of laying (fresh eggs), and after one, two , three, and four weeks.

Preparation of Arabic gum and chitosan solutions:

According to Sariyel et al. [29], a 10% solution of Arabic gum was prepared using the following method. A total of 100 g of Arabic gum (Acacia Senegal, in powdered form, obtained from the Faculty of Science, Tanta University) was accurately weighed into a flask, then diluted to a final volume of 1000 mL using ultrapure water. The mixtures were homogenized by stirring on a magnetic stirrer at 500 rpm and ambient temperature for 10 hours. Afterward, the solutions were stored in a refrigerator at +4 ℃ without agitation overnight.

Following the protocol described by Xing et al. [30], a chitosan solution for egg coating was prepared as follows: A specific amount of chitosan (with a deacetylation grade of 75%, sourced from Sigma Aldrich) was gradually added to a dilute acetic acid solution (typically 1% v/v) to aid in its dissolution. This mixture was then continuously stirred at room temperature using a magnetic stirrer for about 10 to 12 hours until a homogeneous, film-forming solution was achieved. The resulting solution was filtered to remove any undissolved particles and stored at 4°C until needed. All solutions were prepared one day before their intended use

Coating Treatment and Storage of Eggs

Eggs were individually weighed using an analytical balance with a sensitivity of 0.01 g (XB 220A Precisa). Each egg was dipped in chitosan and Arabic gum coating solutions for 1 minute to apply the first layer of coating, then dipped again for another minute to apply the second layer. After coating, the eggs were allowed to dry under a fan, following the method described by Kim et al. [31].

The groups (G1, G2, and G3) were placed in sterile plastic bags with the small end facing down and stored at room temperature (25 ± 1 °C). In contrast, groups (G4, G5, and G6) were kept in a refrigerator at 4 ± 1 °C for 5 weeks. Every week, fifteen eggs from each treatment group were selected for microbiological and quality examinations, which included assessing weight loss, Haugh unit, yolk index, pH, and detecting biogenic amines.

Microbiological Evaluation [32]:

Five eggs from each group were analyzed for aerobic bacteria, thermoduric bacteria, *E. coli*, and yeast-mold.

Eggshell Analysis: Eggs were soaked in 200 ml of 1% sterile buffered peptone water, gently rubbed for one minute, and then subjected to ten-fold serial dilutions for bacteriological examination.

Egg Content Analysis: Eggs were surface sterilized, and the contents were aseptically collected

into a sterile bag and homogenized. A 25-gram sample was diluted in 225 mL of peptone water.

Total aerobic plate counts (APC) were determined using Standard Plate Count Agar at 37°C for 48 ± 2 hours [33]. Thermoduric counts were assessed on tryptone glucose yeast agar at 30°C for 72 hours [34]. *E. coli* was enumerated on Eosin Methylene Blue agar at 37°C for 48 ± 2 hours, and yeast and mold counts were conducted on potato dextrose agar at 25°C for five days [35], with results expressed as $\log_{10}$ CFU/g.

Quality Parameters Determination:

Six groups, each with five eggs, were analyzed for weight loss, yolk index, Haugh unit, and pH.

Weight Loss [36]:

Initial weights of eggs were recorded before storage, and weight loss was calculated with the formula:

Weight Loss (%) = [(Initial Weight – Final Weight) / Initial Weight] × 100.

Yolk Index [37]:

Eggs were cracked onto a smooth surface, and yolk diameter and height were measured. The Yolk Index was calculated as:

Yolk Index = Yolk Height / Yolk Diameter.

Haugh Unit [38]:

Calculated using: Haugh unit = 100 × log (h – 1.7 w^0.37 + 7.51),

Where h is the albumen height (mm) and w is egg weight (g), with h being the average of three measurements from the thick albumen.

PH Determination:

The pH was determined using a digital pH meter (Kasvi model k39-2014B, Paraná, Brazil) previously calibrated with buffer solutions of pH 7 and 10 [39].

Determination of Biogenic Amines by HPLC-UV:

Biogenic amines in whole egg samples were determined using an HPLC-UV method based on the protocol described by de Figueiredo et al. [25], with minor modifications. The whole egg is homogenized, and a 3 g aliquot was extracted with trichloroacetic acid (TCA) in a three-step sequential procedure using 7 mL, 7 mL, and 6 mL of TCA, respectively, resulting in a total volume of 20 mL. The mixture was vigorously shaken and then centrifuged at 12,100 g for 21 minutes at 4 °C, after which the supernatant was filtered. The extracts were stored at –20 °C until further processing. For the derivatization of the extracted biogenic amines, 200 µL of the extract was mixed with 400 µL of saturated sodium bicarbonate solution and 800 µL of dansyl chloride solution. After a brief vortex, the mixture was incubated at 60 °C in the dark for 5 minutes to facilitate the derivatization process. Subsequently, 200 µL of L-proline was added and the mixture was vortexed again. The reaction was allowed to proceed at room temperature in the dark for 30 minutes. Following this, 1000 µL of toluene was incorporated, and the sample was mixed for one minute before being centrifuged to achieve phase separation. The organic phase was collected, evaporated under a nitrogen stream at 60 °C, reconstituted in 600 µL of acetonitrile, and finally filtered through a 0.45 µm PTFE membrane. A 100 µL aliquot of the derivatized filtrate was then injected into the HPLC system for analysis.

Biogenic amines were subsequently analyzed using an Agilent 1200 HPLC system equipped with a fluorescence detector set at an excitation wavelength of 330 nm and an emission wavelength of 465 nm [27]. Chromatographic separation was performed on a reverse-phase C18 column (Waters Spherisorb ODS-2, 125 × 4.6 mm, 5 µm) protected by a Waters Spherisorb guard cartridge, with the entire system operated at ambient temperature. A gradient mobile phase of acetonitrile (solvent A) and LC-grade water (solvent B) was applied. The flow rate was initially set at 1.2 mL/min using a 50:50 ratio of solvents A and B and was subsequently adjusted up to 1.8 mL/min over a total run time of 15 minutes [28]. Standard compounds, including various biogenic amines and benzoyl chloride (used as a derivatizing agent in a 2% acetonitrile solution), were procured from Sigma Aldrich. Stock standard solutions were prepared at a concentration of 10 mg/mL in deionized water and stored at 4 °C.

Mix 25, 50, 100, 200, 500, and 1000 µL of stock solution with 1 mL of 2 M NaOH and 1 mL of 2% benzoyl chloride. Then, using the derivatization protocol, obtain standard concentrations of 0.5, 1, 2, 4, 10, and 20 µg/mL with a correlation coefficient > 0.999 (Figure 1). The amines were separated with high selectivity and precision at retention times of 3.231, 4.505, 6.125, and 12.593 minutes for tyramine, histamine, putrescine, and cadaverine, respectively (Figure 2).

Statistical analysis

Data collected were analyzed using the software Statistical Analysis System (SAS). Statistical variations were observed, and the means were separated using Duncan's multiple range test [40].

Results

Microbiological findings

Table 3 presents the impact of edible coatings (chitosan and Arabic gum) and storage conditions on bacterial load on eggshells. Uncoated eggs stored at ambient temperature (Group 1) exhibited the highest total bacterial count (5.91 ± 0.07 $\log_{10}$ cfu/g) by

week 4. Both chitosan and Arabic gum significantly suppressed microbial proliferation, with chitosan proving more effective. Refrigeration enhanced bacterial suppression further, as evidenced by the lowest count observed in chitosan-coated, refrigerated eggs (Group 5), reaching 3.79 ± 0.04 $\log^{10}$ cfu/g.

Table 4 outlines bacterial load trends in egg contents under the same treatment conditions. Microbial counts in uncoated eggs stored at room temperature increased from 2.50 ± 0.05 to 3.72 ± 0.04 $\log_{10}$ cfu/g over the four weeks. Coating with chitosan consistently yielded lower bacterial levels than Arabic gum, with the combination of chitosan and refrigeration achieving the greatest reduction (2.69 ± 0.01 $\log_{10}$ cfu/g). Notably, no detectable levels of aerobic or thermoduric bacteria, *Escherichia coli*, yeasts, or molds were found in any treatment group throughout the storage duration.

Quality Parameters results

Egg weight loss increased over time in all groups, with the highest observed in uncoated eggs at room temperature, reaching 5.50 ± 0.5 by week 4. Chitosan and Arabic gum coatings reduced this loss, with chitosan performing better. Refrigeration further minimized weight loss, especially in chitosan-coated eggs, which recorded the lowest at 1.40 ± 0.4 by week 4 (Table 5).

All egg groups began with the same yolk index (0.44 ± 0.01) at week 0. Over time, values declined, especially in uncoated eggs at room temperature (G1), which dropped to 0.22 ± 0.02 by week 4. Refrigerated, coated eggs (G5 and G6) retained better yolk quality, with G5 (chitosan-coated) showing the highest value (0.33 ± 0.03) at the end (Table 6).

Table 7 indicates that Haugh unit values were initially high across all treatment groups at week 0, confirming the eggs' freshness. As storage progressed, all samples showed a gradual decline, with room temperature eggs without coating (G1) experiencing the most significant drop to 49.54 by week four. In contrast, eggs coated with chitosan and Arabic gum and stored under refrigeration (G5 and G6) maintained higher Haugh unit values of 65.33 and 63.85, respectively, at four weeks.

The pH of eggs increased over time in all experimental groups, with the most significant rise observed in eggs stored at room temperature without coatings, reaching 9.35 ± 0.04 by day 28. Chitosan and Arabic gum coatings helped slow this increase, with chitosan-coated eggs maintaining a lower pH than Arabic gum-coated ones. Refrigeration significantly reduced pH elevation, with the lowest values recorded in chitosan-coated refrigerated eggs (8.28 ± 0.02 on day 28) as shown in Table 8.

Biogenic amines concentration

Table 9 shows that histamine levels, initially undetectable, gradually increased over time under all storage conditions. Uncoated eggs stored at room temperature (G1) had the highest histamine concentrations, reaching 1.06 mg/kg on day 7 and 4.56 mg/kg by day 28. In contrast, eggs that were refrigerated and coated with either chitosan or Arabic gum (G5 and G6) consistently maintained the lowest histamine levels

Under room temperature conditions, uncoated eggs showed the highest tyramine levels, reaching 4.56 ± 0.18 mg/kg by day 28, while edible coatings helped reduce this accumulation. Eggs coated with chitosan had lower tyramine levels than those with Arabic gum, particularly at earlier times. Refrigeration further minimizes tyramine formation, with refrigerated eggs combined with a chitosan coating consistently exhibiting the lowest concentrations (Table 10).

Under room temperature conditions, uncoated eggs showed the highest putrescine accumulation, increasing from a baseline of 0.028 ± 0.012 mg/kg at day 0 to 4.631 ± 0.31 mg/kg by day 28. Edible coatings significantly mitigated this increase, with chitosan-coated eggs exhibiting lower putrescine levels than those coated with Arabic gum. Refrigeration further reduced putrescine formation, and when combined with chitosan coating, it resulted in the lowest measured levels across the storage period (Table 11).

Under room temperature conditions, cadaverine levels increased over time, with uncoated eggs reaching 2.178 ± 0.15 mg/kg by day 28. Edible coatings reduced this accumulation, with chitosan-coated eggs showing lower levels (1.157 ± 0.12 mg/kg) than those coated with Arabic gum (1.99 ± 0.16 mg/kg) at the same time point. Refrigeration further suppressed cadaverine formation; for instance, refrigerated uncoated eggs recorded 1.015 ± 0.05 mg/kg at day 28, while the combination of refrigeration and chitosan coating resulted in the lowest concentration (0.513 ± 0.03 mg/kg) (Table 12)

Table 13 shows that the Biogenic Amine Index (BAI) increases substantially over time in eggs stored at room temperature, with uncoated eggs reaching 14.329 ± 0.4 mg/kg by day 28. In contrast, the use of edible coatings, especially chitosan, significantly reduces BA accumulation, and refrigeration further lowers these levels.

Discussion

Eggs are susceptible to contamination through various pathways, including the penetration of pathogenic bacteria into the internal contents, where they can persist throughout storage and potentially lead to foodborne illnesses [41]. Moreover, the overall quality of eggs naturally declines over time

during storage. This degradation is exacerbated by exposure to elevated temperatures, which accelerates the deterioration of both physical and microbiological egg quality [42]. Additionally, the presence of spoilage microbes in the egg microflora can lead to biochemical degradation, manifesting as discoloration of the albumen and yolk, along with the development of off-odors. Our study highlights the significant impact of storage temperature and edible coatings on microbial stability and quality preservation of table eggs during extended storage. As expected, microbial counts increased over time in all treatment groups; however, the rate and extent of microbial proliferation were strongly influenced by both storage conditions and the type of coating applied. Eggs stored at ambient temperature (25 °C) exhibited the fastest microbial growth, with uncoated samples exceeding the acceptable aerobic plate count threshold 2.5×10^4 cfu/g (4.39 log CFU/g) defined by the Egyptian Organization for Standardization and Quality (EOS) [43] as early as the second week, reaching 4.73 log CFU/g. Even under refrigeration (4 °C), uncoated eggs crossed the acceptable microbial limit by the fourth week, recording counts of 4.62 ± 0.05 log CFU/g. These findings reinforce the notion that refrigeration alone is insufficient to guarantee microbial safety over prolonged storage periods, especially when eggs remain unprotected by external treatments.

By contrast, eggs coated with chitosan demonstrated significantly lower microbial loads throughout the storage duration. At the end of the fourth week, chitosan-coated eggs maintained microbial counts well within the acceptable limits, underscoring the coating's effectiveness in controlling bacterial proliferation. Chitosan's antimicrobial action is well-documented and is primarily attributed to its ability to disrupt microbial cell membranes, chelate essential metal ions, and inhibit enzymatic activity, all of which contribute to suppressed microbial growth and an extended shelf life.

Arabic Gum-coated eggs also outperformed uncoated controls, though their microbial reduction was less pronounced compared to chitosan-treated eggs. The modest antimicrobial activity of Arabic gum likely stems from its ability to form a semi-permeable film on the eggshell surface, reducing moisture loss and limiting gas exchange, which in turn slows microbial growth. However, its lack of intrinsic bioactivity limits its efficacy relative to chitosan, emphasizing the importance of selecting coating materials with inherent antimicrobial properties for optimal preservation outcomes. No *E. coli* colonies were detected in all control and coated eggs during 5 weeks of storage. Similarly, no yeast and mold colonies were detected in all coated eggs within 5 weeks of storage. This may be determined by the adequate sanitary conditions of the birds and the hygienic conditions of their housing. A similar result was observed by Radkowski [44] and Figueiredo et al. [45]. No mold or yeast was present in the shell or in the internal contents of eggs from any sample.

Our result suggests that both chitosan and Arabic gum coatings, especially when combined with refrigeration, are effective in preventing contamination by common spoilage organisms and pathogenic microbes. These results align with previous studies by Suresh et al. [46] and Damir et al. [47], who also reported enhanced microbial safety and extended shelf life in eggs treated with chitosan coatings. These findings agree with those of Modi et al. [48], who also reported that chitosan effectively inhibits microbial growth when used as a coating for eggs.

From an applied perspective, the findings offer promising implications for the egg industry, particularly in regions where consistent cold storage is not feasible. The use of edible coatings, particularly chitosan, offers a natural and cost-effective approach to enhance microbial safety, reduce spoilage, and extend the shelf life of table eggs. Such an approach could substantially decrease post-harvest losses and improve food safety standards in less developed supply chains.

Generally, the weight loss of eggs increases progressively during storage due to the escape of carbon dioxide and water vapor from the albumen through the numerous pores in the eggshell [49]. This moisture and gas loss leads to physical and chemical changes in both the albumen and yolk, contributing to the deterioration of overall egg quality. Therefore, the rate of weight loss is widely recognized as a critical indicator of internal egg quality during storage. In the present study, weight loss increased progressively with storage time at both 25°C and 4°C, aligning with previous findings by Morsy et al. [50], Yimenu et al. [51], and Kılınç et al. [52]. Notably, uncoated eggs exhibited significantly higher weight loss ($p < 0.05$) compared to coated eggs across all conditions. Among coatings, chitosan proved most effective in minimizing weight loss, followed by Arabic gum.

This reduction in weight loss is attributed to the coatings' ability to act as a supplementary barrier to the eggshell's natural cuticle, partially sealing the pores and thereby limiting moisture and gas exchange. These findings align with those of Bhale et al. [53] and Kim et al. [54], who also reported that chitosan coatings significantly reduced weight loss, especially at lower storage temperatures. Additionally, our results are supported by Derelioğlu and Turgay [55], who observed that Arabic gum coatings helped retain egg quality and reduce weight loss, although less effectively than chitosan. The variation in weight loss outcomes across different

studies may be due to factors such as storage duration, temperature, egg size, shell porosity, and the physicochemical properties of the coating materials used. Overall, our findings reinforce the potential of edible coatings particularly chitosan as an effective strategy to enhance the barrier properties of eggshells, reduce weight loss, and extend the shelf life of table eggs during storage Bhale et al. [53].

The yolk index, defined as the ratio of yolk height to its diameter, is widely recognized as a reliable measure of egg freshness. Freshly laid eggs typically have a high yolk index due to the firm structure of the yolk and an intact vitelline membrane. As storage time increases, this index tends to decline, primarily due to the migration of moisture from the albumen into the yolk and the progressive weakening of the yolk membrane [49].

All treatment groups exhibited a gradual reduction in yolk index throughout the 4-week storage period. This pattern is consistent with previous observations by Samli et al. [49], who reported that moisture redistribution within the egg leads to yolk flattening and membrane instability during storage.

Nevertheless, eggs treated with chitosan and Arabic gum coatings, particularly those kept under refrigeration (G5 and G6), showed a significantly slower rate of decline. By week 4, the yolk index values in these groups remained at 0.33 and 0.31, respectively. This supports the findings of Caner and Yüceer [54], who highlighted that chitosan forms a semi-permeable barrier that reduces water vapor and gas transmission, thereby slowing internal egg deterioration.

Sariyel et al. [29] also reported that eggs coated with Arabic gum and stored at 4°C retained better yolk quality compared to those stored at higher temperatures. Similarly, research by Al-Shammari et al. [55] confirmed that natural polymer coatings help preserve yolk structure by strengthening the vitelline membrane and limiting oxidative stress during extended storage.

Statistical analysis revealed a significant effect of storage temperature on yolk index values at all time points ($P < 0.05$). Eggs stored at 4°C consistently maintained higher yolk index readings than those kept at 25°C on days 7, 14, 21, and 28. These results align with previous studies demonstrating that elevated temperatures accelerate the decline in yolk integrity [49,56,57,58].

Conversely, the uncoated control eggs stored at room temperature (G1) experienced a substantial drop in yolk index, reaching as low as 0.22 by the end of the fourth week. This reflects the negative impact of higher ambient temperatures and the absence of a protective layer, which accelerates moisture and gas exchange.

The Haugh Unit (HU) is a widely accepted and reliable indicator of internal egg quality, particularly the condition of the albumen. A higher HU value reflects a firmer, more viscous egg white, which is indicative of freshness. According to Biladeau and Keener [59], the HU is primarily influenced by the height of the thick albumen and the weight of the egg. Fresh eggs typically exhibit HU values between 75 and 85 upon leaving the farm [37].

During storage, HU values generally decrease due to albumen thinning, which results from structural changes in the albumen proteins, including ovalbumin denaturation and the accumulation of degradation-related proteins like clusterin and ovoinhibitor [60]. Additionally, Müller [61] noted that water migration from the albumen to the yolk further contributes to the reduction in albumen height and, consequently, HU.

All egg groups in the present study started with a HU of 82, confirming their initial freshness. However, a noticeable decline in HU was observed over time in all treatment groups. The decline was most pronounced in uncoated eggs stored at room temperature (G1), which dropped sharply to 49.54 by week 4, reflecting significant deterioration in albumen quality. This observation aligns with previous findings that ambient storage accelerates albumen degradation due to increased CO_2 loss and moisture evaporation. [37 ,49]

Conversely, eggs stored under refrigeration and coated with Arabic gum or Chitosan (G5 and G6) maintained significantly higher ($P < 0.05$) HU values throughout the storage period, reaching 65.33 and 63.85 by week 4, respectively. These results are consistent with those of Abeyrathne et al. [62], who emphasized that low-temperature storage helps preserve albumen viscosity by slowing down enzymatic activity and CO_2 diffusion.

Moreover, the findings corroborate those of Lee et al. [63], Bhale et al. [53], No et al. [64], Suresh et al. [46], and Caner et al. [65], all of whom reported that chitosan coatings help maintain albumen quality by forming semi-permeable barriers that minimize gas exchange and moisture loss, thereby stabilizing HU during storage. The superior preservation effect observed with both Arabic gum and chitosan coatings in this study can be attributed to their film-forming capacity and functional bioactivity. Specifically, these coatings exhibit antimicrobial and antioxidant properties, which play a vital role in reducing protein denaturation and maintaining albumen consistency [22,66]. When applied in combination with refrigeration, these natural coatings significantly extend the shelf life of eggs while maintaining their internal quality.

The pH values of eggs stored under different conditions illustrate the effects of coatings and refrigeration on maintaining quality over time.

Uncoated eggs stored at room temperature (G1) showed the highest increase in pH, reaching 9.35 ± 0.04 by day 28. This observation aligns with previous studies indicating that CO_2 loss and protein degradation accelerate in ambient conditions [67]. In contrast, eggs coated with chitosan (G2) and Arabic gum (G3) experienced a slower increase in pH. Chitosan-coated eggs maintained a lower pH of 8.85 ± 0.04 compared to Arabic gum-coated eggs, which reached 9.03 ± 0.04 by day 28. This supports findings that chitosan's antimicrobial properties help limit microbial growth and reduce enzymatic activity responsible for spoilage [68,69]. Refrigeration significantly stabilized pH levels across all groups. Uncoated refrigerated eggs (G4) had a pH of 8.6 ± 0.03 by day 28, much lower than that of the room-temperature eggs. Chitosan-coated refrigerated eggs (G5) showed the lowest pH increase at 8.28 ± 0.02, reinforcing prior research that highlights chitosan's effectiveness in enhancing preservation when used with refrigeration [70]. Arabic gum-coated refrigerated eggs (G6) also maintained lower pH values at 8.38 ± 0.02 compared to their room-temperature counterparts, demonstrating their effectiveness as a moisture barrier [68].

These findings support studies on edible coatings and refrigeration, which emphasize their combined role in extending shelf life and preserving egg quality [67,68,70]. The results suggest that the most effective strategy for minimizing pH fluctuations and preserving freshness is to combine refrigeration with chitosan coating.

Biogenic amines, namely histamine, tyramine, putrescine, and cadaverine, are produced in protein-rich foods primarily through the microbial decarboxylation of amino acids. Their accumulation serves as a recognized marker of microbial spoilage and potential toxicity. The Biogenic Amine Index (BAI), defined as the sum of these four amines, provides an integrated measure of food quality deterioration. Although eggs are generally not considered high-risk for BA accumulation, suboptimal storage conditions can lead to significant increases in BAI. At day 0, fresh eggs in this study exhibited a very low BAI (0.05 ± 0.018 mg/kg), with histamine and tyramine being non-detectable and only trace levels of putrescine (0.028 ± 0.012 mg/kg) and cadaverine (0.022 ± 0.007 mg/kg) present. These baseline values, which confirm minimal microbial activity and low decarboxylase enzyme function, align with the findings of Tabanelli [71] and Feddern et al. [72], reinforcing the utility of BA content as an initial quality gauge in fresh food matrices.

Under room temperature conditions, uncoated eggs (G1) experienced a pronounced increase in BA levels over time. By day 7, histamine reached 1.06 ± 0.08 mg/kg, tyramine 0.8 ± 0.06 mg/kg, and both putrescine and cadaverine were around 0.78–0.76 mg/kg, resulting in a BAI of 3.4 ± 0.1 mg/kg. By day 28, the BAI escalated to 14.329 ± 0.4 mg/kg. This rapid accumulation indicates that ambient temperatures create an environment conducive to the proliferation of decarboxylase-positive bacteria, which in turn accelerates the synthesis of biogenic amines. The observations are consistent with Yang et al. [73], who demonstrated enhanced decarboxylase activity at such temperatures, and with Li and Zhang [74], who reported that room temperature storage favors bacterial growth and BA accumulation.

The application of edible coatings significantly altered the BA accumulation profile. Eggs treated with Arabic gum (G2) stored at room temperature exhibited lower BA levels with histamine and tyramine values of 0.24 ± 0.05 and 0.38 ± 0.04 mg/kg, respectively, leading to a BAI of 1.325 ± 0.08 mg/kg by day 7, compared to uncoated eggs. Similarly, chitosan-coated eggs (G3) showed intermediate BA levels, with a BAI of 2.71 ± 0.11 mg/kg. These coatings likely act by forming a barrier that restricts moisture and oxygen ingress, thereby inhibiting microbial growth and enzymatic decarboxylation. This mechanism has been substantiated by studies such as Yang et al. [75] and Işıtan et al. [76], which detail the barrier properties and antimicrobial effect of edible coatings in food preservation.

Refrigeration markedly curtailed BA formation. Uncoated eggs stored at low temperatures (G4) recorded a BAI of only 0.457 ± 0.03 mg/kg on day 7, a clear indication that lower temperatures slow microbial and enzymatic processes. When refrigeration was combined with edible coatings, the protective effect was even more pronounced. For example, refrigerated eggs with a chitosan coating (G5) exhibited the lowest BA accumulation, 0.147 ± 0.03 mg/kg on day 7, rising to 2.377 ± 0.1 mg/kg by day 28. Refrigerated eggs treated with Arabic gum (G6) also showed significantly reduced BA levels compared with room temperature samples. Studies by Chung-Saint Lin et al. [77], Esposito et al. [78], and Diaz et al. [79] support these findings by demonstrating that refrigeration, even without additional interventions, considerably delays BA synthesis by reducing bacterial metabolism and decarboxylation enzyme activity.

The significant variability in BA levels across storage conditions highlights two critical control factors: temperature management and edible coating application. Refrigeration reduces microbial growth by slowing down cellular metabolism, while coatings such as chitosan and Arabic gum provide an additional barrier against spoilage. Chitosan, in particular, has intrinsic antimicrobial properties; it disrupts bacterial membranes and reduces enzymatic activity [76,80,81]. In parallel, Arabic gum offers enhanced moisture barrier effects, which further slow microbial proliferation [82,83,84]. From a health and regulatory perspective, even though the absolute BA

levels may not always reach the critical limits for high-risk foods, the cumulative effect, as measured by the BAI, is an important quality marker. High BAI values can indicate early-stage spoilage, which may compromise the sensory attributes and consumer acceptance of eggs.

Vasoactive amines such as histamine and tyramine are particularly significant from a toxicological standpoint, as their formation is closely linked to decarboxylase activity in specific bacteria [73,85]. In this study, uncoated eggs at room temperature accumulated high levels of these amines, whereas refrigeration and edible coatings effectively limited their concentration [86,87]. Although putrescine and cadaverine are generally less toxic, they can potentiate the effects of histamine and are associated with flavor deterioration. Sánchez-Pérez et al. [88] have shown that the presence of these diamines can impede the degradation of histamine by diamine oxidase, thereby exacerbating potential health risks. Notably, their accumulation was minimized under refrigeration and in eggs treated with chitosan coatings.

The Biogenic Amine Index (BAI), calculated as the sum of histamine, tyramine, putrescine, and cadaverine, serves as a reliable indicator of microbial spoilage and overall quality loss in protein-rich foods such as eggs [89]. In fresh eggs (day 0), the BAI was very low (0.05 ± 0.018 mg/kg), confirming minimal microbial activity and limited enzymatic decarboxylation. This initial quality is consistent with previous observations that freshly handled eggs typically exhibit negligible BA levels [71,72].

As storage time increased, untreated eggs kept at room temperature (G1) showed a significant escalation in BAI, reaching 14.329 ± 0.4 mg/kg by day 28. This increase reflects rapid microbial growth and enhanced enzyme activity under ambient conditions, which accelerate the decarboxylation process. Studies by Yang et al. [73] and Li and Zhang [74] further support the idea that room temperature conditions promote the proliferation of decarboxylase-positive bacteria, leading to faster biogenic amine synthesis.

In contrast, eggs treated with edible coatings exhibited much lower BAIs. At room temperature, chitosan-coated eggs (G2) and Arabic gum-coated eggs (G3) on day 7 recorded BAIs of 1.325 ± 0.08 mg/kg and 2.71 ± 0.11 mg/kg, respectively, with subsequent increases remaining considerably below the levels detected in untreated eggs. Moreover, refrigeration markedly retarded BA formation: uncoated eggs stored in the refrigerator (G4) achieved a BAI of 0.457 ± 0.03 mg/kg on day 7. When refrigeration was combined with edible coatings, the effect was even more profound; for instance, refrigerated eggs with a chitosan coating (G5) maintained a BAI of only 0.147 ± 0.03 mg/kg on day 7 and 2.377 ± 0.1 mg/kg by day 28, while refrigerated, Arabic gum-treated eggs (G6) also showed reduced spoilage compared to their room temperature counterparts.

These findings underscore the dual benefit of proper temperature management and the application of antimicrobial edible coatings in spoilage control. Refrigeration slows down both microbial proliferation and the enzymatic reactions responsible for biogenic amine formation, while coatings such as chitosan and Arabic gum create physical barriers that limit oxygen and moisture transfer. Chitosan, in particular, exhibits strong intrinsic antimicrobial properties that effectively inhibit bacterial growth [76,86]. This combined strategy not only minimizes the risk of BA-related toxicity but also enhances product quality and extends shelf life.

From a health and regulatory perspective, even if the BA levels in these eggs do not reach the critical limits set for some high-risk foods, their cumulative effect, as reflected by the BAI, is a valuable quality marker. Elevated BAI values can signal early-stage spoilage, which may compromise sensory qualities and consumer acceptance [67,89].

Conclusions

This study shows that both storage temperature and natural edible coatings, specifically chitosan and Arabic gum, are crucial for maintaining the quality and safety of table eggs during storage. The combination of chitosan coating and refrigeration was the most effective, reducing weight loss, stabilizing yolk and Haugh unit values, limiting pH changes, and providing strong antimicrobial protection. This approach significantly lowered harmful biogenic amines, enhancing shelf life and consumer safety. The findings support the use of biodegradable, food-grade coatings with cold storage as a cost-effective and sustainable method for maintaining egg quality, particularly in areas with limited cold chain logistics. Overall, chitosan outperformed Arabic gum in antimicrobial efficacy, suggesting a practical solution to reduce post-harvest losses and improve public confidence in the egg industry while promoting eco-friendly preservation technologies.

Recommendations

It is recommended to apply chitosan coatings and store eggs at a refrigerated temperature of 4 ± 1 °C to maximize microbial stability and to preserve the physical and chemical quality of the eggs over time. This approach significantly reduces weight loss, bacterial growth, and spoilage indicators, including biogenic amines. As a result, it is the most effective strategy for extending the shelf life and maintaining the safety of fresh table eggs.

Acknowledgment

All great thanks to the Department of Chemistry, Toxicology, and Feed Deficiency at the Animal Health Research Institute for their excellent support and completion of this study.

Conflicts of interest

According to the authors, there isn't a conflict of interest.

Funding statement

There's no funding source.

TABLE 1. Experimental design for coated eggs stored at room temperature and in the refrigerator for different periods

	Temperature	Chitosan	Arabic Gum
G1	R.T. (25 ± 1 °C)	-	-
G2		+	-
G3		-	+
G4	Refrigerator (4 ± 1 °C)	-	-
G5		+	-
G6		-	+

TABLE 2. Timetable of the gradient mode of mobile phase and flow rate.

Time	A	B	Flow rate (mL/ min.)
2	60	40	1.5
4	70	30	1.8
8	80	20	1.8

TABLE 3. Effect of Edible Coatings (Chitosan and Arabic Gum) and Storage Temperature on the Total Bacterial Count of Table Eggs shell During the Storage Period

Time	G1	G2	G3	G4	G5	G6
W0	3.70 ± 0.01^{a}	3.41 ± 0.02^{b}	3.55 ± 0.07^{b}	3.70 ± 0.01^{a}	3.41 ± 0.02^{b}	3.55 ± 0.07^{b}
W1	4.32 ± 0.1^{a}	3.69 ± 0.09^{d}	3.82 ± 0.04^{b}	3.79 ± 0.07^{c}	3.52 ± 0.03^{e}	3.67 ± 0.03^{d}
W2	4.73 ± 0.08^{a}	3.87 ± 0.03^{c}	3.95 ± 0.05^{b}	3.91 ± 0.04^{b}	3.61 ± 0.05^{d}	3.78 ± 0.03^{c}
W3	5.40 ± 0.1^{a}	4.14 ± 0.1^{c}	4.44 ± 0.07^{b}	4.35 ± 0.03^{b}	3.69 ± 0.01^{e}	3.86 ± 0.03^{d}
W4	5.91 ± 0.07^{a}	4.22 ± 0.04^{d}	4.87 ± 0.07^{c}	4.62 ± 0.05^{b}	3.79 ± 0.04^{e}	4.13 ± 0.06^{d}

The mean difference was significant at the P<0.05 level between all treatments

TABLE 4. Effect of Edible Coatings (Chitosan and Arabic Gum) and Storage Temperature on the thermoduric bacterial count of Table Eggs content During the Storage Period.

	G1	G2	G3	G4	G5	G6
W 0	2.50 ± 0.05^{a}	2.25 ± 0.08^{c}	2.39 ± 0.04^{b}	2.50 ± 0.05^{a}	2.25 ± 0.08^{c}	2.39 ± 0.04^{b}
W1	3.18 ± 0.07^{a}	2.41 ± 0.03^{d}	2.59 ± 0.09^{c}	2.69 ± 0.05^{b}	2.38 ± 0.07^{d}	2.54 ± 0.1^{c}
W2	3.28 ± 0.02^{a}	2.53 ± 0.03^{d}	2.66 ± 0.1^{c}	2.72 ± 0.04^{b}	2.51 ± 0.1^{d}	2.62 ± 0.02^{c}
W3	3.43 ± 0.03^{a}	2.71 ± 0.02^{d}	3.23 ± 0.4^{b}	2.82 ± 0.02^{c}	2.57 ± 0.01^{e}	2.79 ± 0.04^{d}
W4	3.72 ± 0.04^{a}	2.75 ± 0.07^{d}	3.33 ± 0.04^{b}	3.11 ± 0.04^{c}	2.69 ± 0.01^{e}	2.93 ± 0.02^{d}

The mean difference was significant at P<0.05 level between all treatments

TABLE 5. Effect of edible coating (Chitosan and Arabic Gum), and storage temperature on weight loss of the examined table eggs during the storage period

Storage period	G1	G2	G3	G4	G5	G6
W 0	0	0	0	0	0	0
W 1	1.46 ± 0.25^{a}	1 ± 0.30^{c}	1.3 ± 0.3^{b}	0.60 ± 0.3^{d}	0.30 ± 0.11^{f}	0.4 ± 0.2^{e}
W 2	2.56 ± 0.02^{a}	1.76 ± 0.25^{c}	2.2 ± 0.2^{b}	1.1 ± 0.1^{d}	0.6 ± 0.10^{f}	0.8 ± 0.2^{e}
W 3	3.76 ± 0.04^{a}	2.40 ± 0.4^{c}	3.4 ± 0.4^{b}	1.70 ± 0.2^{d}	0.9 ± 0.1^{f}	1.24 ± 0.07^{e}
W 4	5.50 ± 0.5^{a}	3.20 ± 0.20^{c}	3.8 ± 0.2^{b}	2.5 ± 0.2^{d}	1.40 ± 0.4^{f}	1.8 ± 0.04^{e}

The mean difference was significant at $P<0.05$ level between all treatments

TABLE 6. Effect of edible coating (chitosan and Arabic gum), and storage temperature on the yolk index of the examined table eggs during the storage period.

Storage period	G1	G2	G3	G4	G5	G6
W 0	0.44 ± 0.01^{a}	0.44 ± 0.01^{a}	0.44 ± 0.01^{a}	0.44 ± 0.01^{a}	0.44 ± 0.01^{a}	0.44 ± 0.01^{a}
W 1	$0.35\pm0.0.02^{f}$	0.38 ± 0.02^{d}	0.37 ± 0.01^{e}	0.39 ± 0.02^{c}	0.41 ± 0.01^{a}	0.40 ± 0.02^{b}
W 2	0.32 ± 0.02^{f}	0.35 ± 0.01^{d}	0.34 ± 0.01^{e}	0.36 ± 0.01^{c}	0.38 ± 0.02^{a}	0.37 ± 0.03^{b}
W 3	0.27 ± 0.02^{f}	0.32 ± 0.02^{d}	0.30 ± 0.02^{e}	0.31 ± 0.01^{c}	0.34 ± 0.005^{a}	0.33 ± 0.03^{b}
W 4	0.22 ± 0.02^{e}	0.28 ± 0.02^{c}	0.25 ± 0.04^{d}	0.30 ± 0.01^{b}	0.33 ± 0.03^{a}	0.31 ± 0.01^{b}

The mean difference was significant at $P<0.05$ level between all treatments

TABLE 7. Effect of edible coating (Chitosan and Arabic gum), and storage temperature on the albumin Haugh of the examined table eggs during the storage period.

Storage period	G1	G2	G3	G4	G5	G6
W 0	82.46 ± 2.9^{a}	82.46 ± 1.9^{a}	82.46 ± 1.9^{a}	82.43 ± 1.8^{a}	82.50 ± 1.9^{a}	82.50 ± 1.9^{a}
W 1	71.63 ± 0.71^{f}	76.16 ± 0.30^{d}	75.39 ± 0.56^{e}	77.26 ± 0.80^{c}	79.33 ± 0.65^{a}	78.66 ± 0.75^{b}
W 2	66 ± 1.0^{f}	70.53 ± 0.50^{d}	68.79 ± 0.76^{e}	71.57 ± 0.83^{c}	75.43 ± 0.55^{a}	73.46 ± 0.61^{b}
W 3	53 ± 1.0^{f}	62.56 ± 0.59^{d}	60.46 ± 0.56^{e}	65.45 ± 0.56^{c}	70.29 ± 0.52^{a}	68.76 ± 0.75^{b}
W 4	49.54 ± 0.63^{f}	58.52 ± 0.51^{d}	56.15 ± 0.63^{e}	62.36 ± 0.71^{c}	65.33 ± 0.60^{a}	63.85 ± 0.50^{b}

Different small letters indicate significance between groups at $p < 0.05$

TABLE 8. pH values in eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	7.6 ± 0.05					
W 1	8.33 ± 0.04	8.12 ± 0.04	8.24 ± 0.03	7.94 ± 0.03	7.78 ± 0.02	7.92 ± 0.03
W 2	8.84 ± 0.05	8.42 ± 0.04	8.62 ± 0.04	8.2 ± 0.03	7.99 ± 0.03	8.1 ± 0.03
W 3	9.1 ± 0.03	8.62 ± 0.04	8.84 ± 0.05	8.4 ± 0.03	8.1 ± 0.03	8.2 ± 0.03
W 4	9.35 ± 0.04	8.85 ± 0.04	9.03 ± 0.04	8.6 ± 0.03	8.28 ± 0.02	8.38 ± 0.02

Different small letters indicate significance between groups at $p < 0.05$

TABLE 9. Histamine (mg/kg) concentrations in eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	nd	Nd	nd	nd	Nd	Nd
W 1	1.06 ± 0.08^{a}	0.24 ± 0.05^{c}	0.82 ± 0.10^{b}	0.155 ± 0.03^{d}	0.032 ± 0.01^{f}	0.063 ± 0.01^{e}
W 2	2.07 ± 0.18^{a}	0.97 ± 0.12^{c}	1.47 ± 0.17^{b}	0.77 ± 0.05^{c}	0.37 ± 0.07^{e}	0.58 ± 0.06^{d}
W 3	3.02 ± 0.11^{a}	1.78 ± 0.16^{c}	2.63 ± 0.13^{b}	1.099 ± 0.08^{d}	0.482 ± 0.04^{f}	0.927 ± 0.06^{e}
W 4	4.56 ± 0.18^{a}	2.19 ± 0.09^{c}	3.74 ± 0.21^{b}	1.88 ± 0.09^{d}	0.516 ± 0.04^{f}	1.284 ± 0.1^{e}

Nd (not detected) < 0.015 mg/ kg.
Different small letters indicate significance between groups at $p < 0.05$

TABLE 10. Tyramine (mg/kg) concentrations in eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	Nd					
W 1	0.8 ± 0.06^{a}	0.38 ± 0.04^{b}	0.65 ± 0.06^{a}	0.046 ± 0.01^{c}	0.018 ± 0.01^{d}	0.039 ± 0.01^{c}
W 2	1.03 ± 0.07^{a}	0.446 ± 0.05^{c}	0.89 ± 0.08^{b}	0.409 ± 0.04^{cd}	0.159 ± 0.02^{e}	0.4 ± 0.04^{d}
W 3	3.02 ± 0.11^{a}	1.78 ± 0.16^{c}	2.63 ± 0.13^{b}	1.099 ± 0.08^{d}	0.482 ± 0.04^{e}	0.927 ± 0.06^{d}
W 4	4.56 ± 0.18^{a}	2.19 ± 0.09^{c}	3.74 ± 0.21^{b}	1.88 ± 0.09^{d}	0.516 ± 0.04^{f}	1.284 ± 0.1^{e}

Nd (not detected) < 0.002 mg/ kg.
Different small letters indicate significance between groups at $p < 0.05$

TABLE 11. Putrescine (mg/kg) concentrations in eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	0.028 ± 0.012					
W 1	0.78 ± 0.07^{a}	0.318 ± 0.02^{c}	0.6 ± 0.06^{b}	0.196 ± 0.02^{d}	0.079 ± 0.02^{f}	0.161 ± 0.02^{e}
W 2	1.64 ± 0.14^{a}	0.86 ± 0.05^{b}	1.59 ± 0.13^{a}	0.856 ± 0.08^{b}	0.41 ± 0.04^{c}	0.82 ± 0.06^{b}
W 3	3.68 ± 0.13^{a}	1.7 ± 0.07^{c}	3.01 ± 0.11^{b}	1.2 ± 0.13^{d}	0.489 ± 0.05^{f}	0.99 ± 0.094^{e}
W 4	4.631 ± 0.31^{a}	3.2 ± 0.29^{b}	4.648 ± 0.27^{a}	1.571 ± 0.11^{c}	0.855 ± 0.07^{e}	1.22 ± 0.07^{d}

Different small letters indicate significance between groups at $p < 0.05$.

TABLE 12. Cadaverine (mg/kg) concentrations in eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	0.022 ± 0.007					
W 1	0.76 ± 0.06^{a}	0.387 ± 0.04^{c}	0.64 ± 0.06^{b}	0.06 ± 0.01^{d}	0.018 ± 0.009^{e}	0.048 ± 0.01^{d}
W 2	0.986 ± 0.05^{a}	0.465 ± 0.05^{c}	0.83 ± 0.07^{b}	0.337 ± 0.03^{d}	0.118 ± 0.02^{f}	0.234 ± 0.02^{e}
W 3	1.47 ± 0.06^{a}	0.703 ± 0.03^{b}	1.29 ± 0.07^{a}	0.525 ± 0.04^{c}	0.25 ± 0.02^{e}	0.424 ± 0.03^{d}
W 4	2.178 ± 0.15^{a}	1.157 ± 0.12^{b}	1.99 ± 0.16^{a}	1.015 ± 0.05^{b}	0.513 ± 0.03^{d}	0.85 ± 0.05^{c}

Different small letters indicate significance between groups at $p < 0.05$.

TABLE 13. BAI for eggs coated with chitosan and Arabic gum were stored at room temperature and in the refrigerator for different intervals [mean ± se, n=10].

Storage period	G1	G2	G3	G4	G5	G6
W 0	0.05 ± 0.018					
W 1	3.4 ± 0.1^{a}	1.325 ± 0.08^{c}	2.71 ± 0.11^{b}	0.457 ± 0.03^{d}	0.147 ± 0.03^{f}	0.311 ± 0.02^{e}
W 2	5.726 ± 0.16^{a}	2.741 ± 0.14^{c}	4.78 ± 0.2^{b}	2.372 ± 0.11^{d}	1.057 ± 0.07^{f}	2.034 ± 0.09^{e}
W 3	10.098 ± 0.25^{a}	5.12 ± 0.23^{c}	8.66 ± 0.23^{b}	3.44 ± 0.2^{d}	1.529 ± 0.11^{f}	2.891 ± 0.17^{e}
W 4	14.329 ± 0.4^{a}	7.997 ± 0.3^{c}	13.105 ± 0.42^{b}	5.398 ± 0.1^{d}	2.377 ± 0.1^{f}	4.138 ± 0.15^{e}

Different small letters indicate significance between groups at $p < 0.05$.

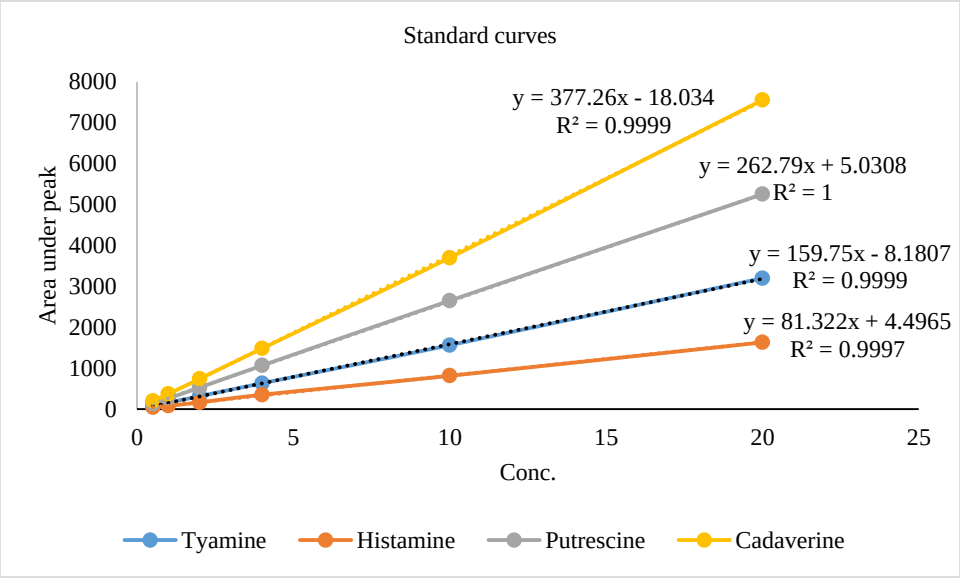

Fig. 1. Calibration plots for tyramine, histamine, putrescine, cadaverine biogenic amines by HPLC at the range of 0.5-20 ppm.

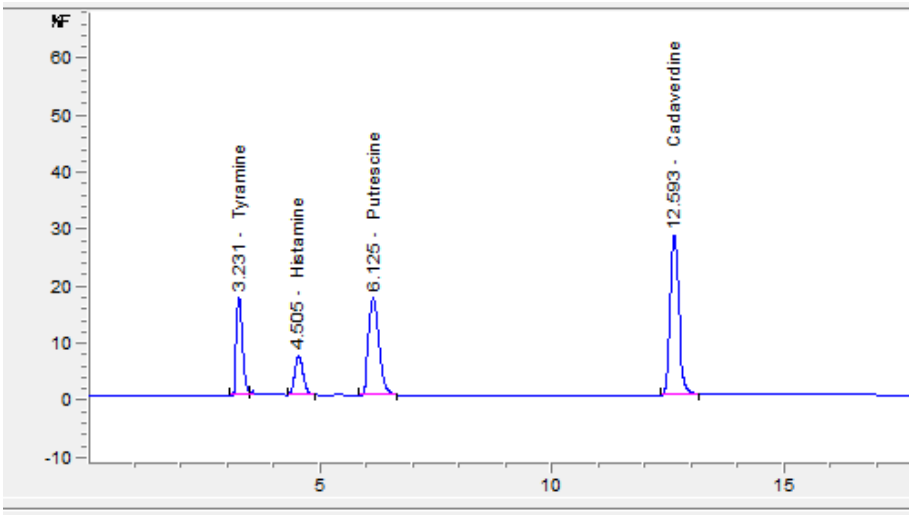

Fig. 2. chromatogram of the separated biogenic amines at 1 mg/kg by HPLC.

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تعزيز مدة صلاحية البيض وسلامته: دراسة مقارنة لطلاء الشيتوزان والصمغ العربي في ظروف التخزين المحيطة والتبريد

حنان رجب غنايم[١]، أمل فوزي البنا[١]،محمد صالح[٢]، جميلات أبو المجد السيد[٣]، إيمان السيد الخواجة[٣]، أروى حسن نصار[٣]، فاضل عبد الفتاح محمد[٤] و مها صبري عبد الحفيظ[٥]

[١] قسم صحة الأغذية، معهد بحوث الصحة الحيوانية الفرعى، طنطا، مركز البحوث الزراعية، مصر.

[٢] المعمل المرجعي للرقابة البيطرية على جودة إنتاج الدواجن، معهد بحوث الصحة الحيوانية ، مركز البحوث الزراعية، الدقي، الجيزة، مصر.

[٣] قسم صحة الأغذية ، معهد بحوث الصحة الحيوانية الفرعى، المنصورة، مركزالبحوث الزراعية, مصر.

[٤] قسم صحة الأغذية، معهد بحوث الصحة الحيوانية الفرعى،سوهاج، مركز البحوث الزراعية، مصر.

[٥] قسم الكيمياء الحيوية والسموم والنقص الغذائى، معهد بحوث الصحة الحيوانية ، الدقى، مركز البحوث الزراعية، مصر.

الملخص

بيض الدجاج الطازج غنيٌّ بالعناصر الغذائية، ولكنه سريع التلف نظرًا لطبيعة قشرته المسامية والهشة. قيّمت هذه الدراسة تأثير الطلاءات الصالحة للأكل ودرجة حرارة التخزين على جودة بيض المائدة واستقراره الميكروبي على مدى خمسة أسابيع. غُطي البيض بالشيتوزان أو الصمغ العربي، وجُفّف، وخُزّن إما في درجة حرارة الغرفة (٢٥±١ درجة مئوية) أو في الثلاجة (٤±١ درجة مئوية). شملت التقييمات الأسبوعية العد الميكروبيولوجي، ونسبة فقدان الوزن، ومؤشر الصفار، ووحدة هاو، والأمينات الحيوية. أشارت النتائج إلى أن البيض غير المغلف والمُخزّن في درجة حرارة الغرفة أظهر أعلى مستويات الأحمال الميكروبية، ونسبة فقدان الوزن، ومؤشرات التلف. ثبّط طلاء الشيتوزان نمو البكتيريا وتكوين الأمينات الحيوية بشكل ملحوظ مقارنةً بالصمغ العربي. أظهر البيض المبرد المغلف بالشيتوزان حفظًا ممتازًا، مع أقل عدد إجمالي للبكتيريا (٣.٧٩ و٢.٦٩ لوغاريتم/غ) على التوالي، وخسارة ضئيلة في الوزن (١.٤٠±٠.٤%)، مع الحفاظ على جودة الصفار والبياض. وكانت الأمينات الحيوية، بما في ذلك التيرامين والبيوتيريسين والكادافيردين، الأقل في هذه المجموعة، مما يدعم فعالية الجمع بين طلاء الشيتوزان والتخزين البارد في الحفاظ على نضارة البيض وسلامته.

الكلمات الدالة: بيض المائدة، طلاء صالح للأكل، شيتوزان، صمغ عربي، مدة الصلاحية، وحدة هاو، أمين حيوي.