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Original Article

The Effect of Coatings of Carboxymethyl Cellulose, Titanium Oxide, and Silica Nanoparticles on Improving the Shelf Life of Table Eggs Stored at Refrigeration Temperature

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Abstract

This study was conducted to evaluate the effect of carboxymethyl cellulose (CMC), titanium dioxide (TiO_2) nanoparticle, and silica dioxide (SiO_2) coatings on the egg weight, interior egg quality, egg components and bacterial count of table eggs stored in refrigerator temperature (8°C). Two hundred and forty fresh eggs were divided into six treatment groups: T1 (control, uncoated), T2 (CMC-coated), T3 (SiO_2-coated), T4 (CMC + SiO_2-coated), T5 (TiO_2-coated), and T6 (CMC + TiO_2-coated). The eggs were evaluated during storage periods of 0, 2, 4, 6, and 8 weeks to determine egg weight, interior egg quality, components percentages, and bacterial counts included total bacterial count and coliform bacterial count. The results showed that coatings containing SiO_2 (T3), CMC + SiO_2 (T4), TiO_2 (T5), and CMC + TiO_2 (T6) maintained superior egg quality including egg weight, Haugh Unit, yolk index, and optimal proportions of egg components. These treatments significantly outperformed coating with CMC alone (T2) and the uncoated control (T1), which showed the lowest values. Furthermore, bacterial analysis revealed a significant reduction in total bacterial count and coliform counts in the first day of coating and throughout storage periods, with T3 and T5 having the lowest bacterial counts, followed by T4 and T6. In contrast, T1 consistently recorded the highest bacterial counts. During storage, uncoated eggs (T1) showed rapid bacterial growth, whereas coated eggs, especially those treated with CMC + TiO_2 (T6) and CMC + SiO_2 (T4), maintained significantly lower bacterial counts. In conclusion, the use of CMC with TiO_2 or SiO_2 nanoparticles proved to be highly effective in improving egg weight, egg quality characteristics, and extending shelf life when stored at refrigerated temperature (8°C), representing a promising approach for table eggs preservation.

Categories: Food packaging, Food quality, Nanotechnology for sustainable agriculture

Keywords: table eggs, cmc, sio2, tio2, shelf life, refrigerator temperature

Introduction

Table eggs are an important protein food source due to its high nutritional value. It contains high levels of proteins, essential fatty acids, fat-soluble vitamins, antioxidants, carotenoids, and phospholipids, all of which are low in glucose. Table eggs, like milk are perishable foods, which deteriorate rapidly if stored under poor conditions [1-3].

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Eggs are at their optimum quality after laying, but their qualitative, chemical, and microbial properties begin to deteriorate rapidly over time [4]. Egg storage results in loss of moisture and carbon dioxide content, resulting in decreased egg weight and deterioration of internal quality. Therefore, research and studies indicate the need to find optimal storage conditions to limit the deterioration of properties [4,5]. Various types of materials have been used for coating table eggs, these coating materials are used in egg packaging to seal the shell's pores by creating a synthetic barrier, these materials prevent the loss of moisture and carbon dioxide, effectively increase the thickness of shell to preserve internal quality [6,7]. To control this problem, various types of mineral oils [4-8], natural and medicinal oils [9,10], carboxymethyl and chitosan [11], and sericin [12], keratin and fibroin [13], pectin [14-16], proteins and protein isolates [17], propolis [18], edible coating citric acid and zein proteins [19,20] can be used. Water-soluble carboxymethyl cellulose (CMC or gum) is one of the most important and widely used thickeners in ice cream and food production [21]. Several studies recommend its use as an effective coating material for table eggs, as it reduces the deterioration of the internal quality of the eggs and reduces the number of bacteria in the shell [22,23]. There is currently a significant global trend toward the use of nanomaterials and composites to preserve various types of food [24], and they have been successfully used to preserve and extend the shelf life of table eggs [25]. TiO_2 is a white, thermally stable, poorly soluble, inorganic solid that is not classified as a hazardous substance according to the Codex Alimentarius des Nations Unites. It has been recognized as non-toxic by the Food and Drug Administration (FDA) and has been used in human nutrition, pharmaceuticals, and food-contact materials. It is currently used as a preservative. Silicon is used as a bleaching or brightening agent in many applications such as paints, cosmetics, and food products, it is used in environmental applications to remove many water and air pollutants. Silicon is a bioactive polyvalent mineral abundant in the environment (28%) and rarely occurs naturally. Generally, silicon found as silicon dioxide (silicone) or complex silicates due to its strong affinity for oxygen. The importance of silicon in the diet has been demonstrated by its disadvantages, such as altered liver and long bone composition and reduced joint stiffness. To date, no formal recommendations have been issued regarding silicon concentrations in commercial foods [26].

This study aimed to determine the effect of using nanoparticles of carboxymethyl cellulose (CMC), titanium oxide (TiO_2), and silica (SiO_2) as coating materials on egg weight, egg quality characteristics, components, and bacterial count during the storage for 2, 4, 6, and 8 weeks at refrigeration temperature (8°C).

Materials And Methods

Period of the study

This study was carried out at the College of Agriculture, University of Tikrit, during the period from March 22, 2023 to May 18, 2023, to study the effect of some coating material on eggweight, egg quality characteristics, egg components, and bacterial count during 0, 2, 4, 6, and 8 weeks at refrigerator storage.

Egg collection

A total of 240-day old table eggs were obtained from Al-Mustafa Company in Salah Al-Din Governorate, Samarra District, central Iraq, which specializes in producing table eggs from 21-week-old Lohmann commercial laying hens, Turkish origin.

Egg coating materials

Food grade CMC was obtained from local markets and prepared by dissolving 1 g in 100 ml of sterile normal saline (1%) (pharmacy grade) and stir until dissolved. Nanoparticles of SiO_2 and TiO_2 obtained in cooperation with Northeast Agricultural University (NEAU) in China, 1 gm of nanoparticles of SiO_2 and TiO_2 were dissolved in 100 ml of sterile normal saline, the combination of CMC and nanoparticles of SiO_2 and TiO_2 were prepared by adding 1 g of nanoparticles to the CMC solutions directly, final concentration (1% nanoparticle and 1% CMC). The size and purity of the nanomaterials and CMC used in the experiment were detected using Scanning Electron Microscopy (SEM) model Inspect F50 at Alkhora SEM Lab, Baghdad, Iraq (Table *1*).

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Nanoparticles	Element	Atomic (%)	Atomic (% Error)	Weight (%)	Weight (% Error)
	C	11.9	0.4	7.9	0.2
SiO_2	N	1.4	0.6	1.0	0.3
	O	66.3	0.4	58.5	0.3
	Si	21.7	0.1	33.6	0.1
	C	17.5	0.6	9.3	0.3
	N	2.0	0.7	1.2	0.4
TiO_2	O	56.0	1.5	39.4	1.1
	Al	1.8	0.1	2.1	0.1
	Si	0.5	0.0	0.7	0.1
	Ti	21.7	0.1	45.7	0.2
	Zn	0.5	0.0	1.5	0.1
	C	10.3	0.4	8.0	0.2
CMC	N	2.1	0.8	1.4	0.5
	O	58.5	1.6	38.2	1.2
	Zn	0.6	0.2	1.1	0.1
	Si	-	-	-	-
	Ti	-	-	-	-

TABLE 1: Chemical analysis and sizes of the nanoparticles and CMC.

Nanoparticles: SiO_2, TiO_2, and CMC, Carboxymethyl Cellulose

Egg treatments

On the day of egg collection, eggs were immediately distributed into six treatment groups:

T1: 40 uncoated eggs as a control group.

T2: 40 eggs coated with CMC.

T3: 40 eggs coated with SiO_2.

T4: 40 eggs coated with CMC + SiO_2.

T5: 40 eggs coated with TiO_2.

T6: 40 eggs coated with CMC + TiO_2.

All egg groups were sprayed with each solution (5 ml/egg) using a hand sprayer, then left to dry in their containers, and then stored in a refrigerator at a constant temperature of 8°C and relative humidity of 60-65°C immediately after treatment.

Storage periods

All eggs were stored for 0, 2, 4, 6, and 8 weeks. During each period, five eggs were randomly collected from each treatment and examined individually for their weight, internal quality index, and bacterial count.

Egg weight

Egg weights were recorded for each egg and for each treatment, and after each storage period, a digital Sartorius balance was used for this purpose, measuring up to 2 g before and after packaging.

Internal egg quality characteristics

All internal egg quality characteristics were measured for each collected egg, according to the method described by Stadelman et al. [4]. These included egg weight, albumen height, yolk height, yolk diameter, and yolk index.

Albumen height, yolk height, and yolk diameter

Albumen and yolk height were measured using a digital vertical micrometer, and yolk diameter was measured using a digital Vernier scale.

Egg component ratio

After cracking the egg and separating the yolk from the albumen, carefully the yolk was separated from the albumen to avoid contaminating the white. Place the yolk on filter paper and flip it over to remove any remaining albumen. Allow the shell to dry at room temperature until the next day. Record the weights of both the yolk and shell (including membranes and the presence of the caps). The weight of the albumen is calculated using the difference method and then calculate the ratio of the three components.

Bacterial count

All bacterial count tests were performed in the Milk Hygiene Laboratory at the College of Veterinary Medicine, University of Baghdad, on three replicates of eggs for each treatment and after each storage period. Eggs were placed in nylon bags containing 100 ml of sterile peptone water (Acomex) under sterile conditions. Decimal dilutions were performed using 10 ml screw-cap bottles. The culture media used for bacterial tests were sterilized at 121°C for 15 minutes and under a pressure of 15 psi. For the different glassware, they were sterilized in an electric oven at 180°C for 3 hours.

Total bacterial count

Total bacteria were counted using the pour-plate method described by Chauhan and Jindal [27], by transferring 1 ml of each decimal dilution using a sterile pipette into two empty sterile Petri dishes (duplicates) and adding it directly to each dish. A 15 ml of sterile culture medium (nutrient agar, Acomex) maintained in a water bath at 46°C was mixed with the dilution well of the bacterial suspension by rotating the two dishes left and right, stirring each time. After the culture medium solidified, the dishes were placed upside down in an incubator at 37°C for 24 hours. Colonies growing in the dishes containing 30-300 colonies were then counted. Bacterial counts were estimated by multiplying the number of colonies by the reciprocal of the dilution to obtain the number per egg.

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Coliform bacterial count

Coliform count was performed using the pour plate method also reported by Chauhan and Jindal [27], which is similar to bacterial enumeration.

Statistical analyses

Data were analyzed using the general linear model procedure of Dmitrienko and Koch [28]. Means were compared using Duncan's multiple range test at a 5% probability [29], all bacterial numbers converted to log numbers before analysis.

Results And Discussion

Egg weight

Table *2* shows table egg coating and storage treatments did not affect the refrigerator temperature, and thus there were no significant differences between the five egg-coating treatments, as their average values reached between 51.23 and 51.27 g, directly after the egg coating and storage in the refrigerator for 1 day, significantly superior ($P < 0.05$) to the egg weight of the first treatment (control), which recorded an average weight of 50.74 g. The different egg coating treatments continued to be significantly superior ($P < 0.05$) to the control treatment (the first treatment), and the differences were not significant among them until 42 days, when they were significantly superior ($P < 0.05$). As the storage period progressed to 56 days, the situation remained the same, as the third, fourth, fifth and sixth treatments were significantly superior ($P < 0.05$) to the second treatment, which in turn was superior to the first treatment, with a significant difference ($P < 0.05$). The overall effect of the treatments indicated that the nanocomposite egg coating treatments were superior to the second treatment, which in turn was significantly superior ($P < 0.05$) to the control treatment (the first treatment). Egg weight is an important quantitative and qualitative trait, as mentioned above. An egg is at its best when it is fresh after being laid by the hen [4]. Egg storage has contributed to the deterioration of egg quality and weight loss, especially when stored for long periods at high temperatures due to the loss of moisture and CO_2 from inside the egg to the outside. Here, we note that egg coating practices clearly contributed to the decrease in egg weight loss as the storage period progress compared to the control treatment, as the egg weight was significantly higher in the coating practices under study. It is also noted that coating contributed to an increase in egg weight immediately after treatment. This is directly attributed to the physical mass of the newly applied of an additional layer and weight to the egg as a result of the presence and addition of the carboxymethyl cellulose coating, in addition to carboxymethyl cellulose and nanomaterials treatments significant differences in the effect of storage periods at refrigerator temperature appeared after 28 days. This is due to the effect of refrigeration conditions, which contribute to reducing egg weight loss during storage and maintaining their quality characteristics. A previous study indicated that treating Japanese quail eggs with oil and cooling them at 5°C (refrigerated) preserve the eggs from deterioration for 120 days [30]. Our results are also consistent with research by Omkarappa et al. [31]. A study conducted also showed that the shelf life of table eggs exceeds 2 months when stored in the refrigerator [32].

Treatments	Storage (day)					Average
	1	14	28	42	56	
T1	50.74 ± 0.79 b	50.06 ± 0.49 b	48.81 ± 0.51 b	47.68 ± 0.49 c	46.17 ± 0.26 c	48.65 ± 0.26 C
T2	51.23± 0.40 a	51.11± 0.26 a	50.71 ± 0.39 a	49.89 ± 0.37 b	49.05 ± 0.33 b	50.40 ± 0.33 B
T3	51.27± 0.55 a	51.13± 0.19 a	50.92 ± 0.09 a	50.77 ± 0.05 a	50.31 ± 0.2 a	50.88 ± 0.2 A
T4	51.25± 0.40 a	51.17± 0.26 a	50.95 ± 0.19 a	50.80 ± 0.37 a	50.42 ± 0.36 a	50.92 ± 0.36 A
T5	51.27± 0.55 a	51.15± 0.18 a	50.96 ± 0.09 a	50.82 ± 0.10 a	50.36 ± 0.12 a	50.71 ± 0.12 A
T6	51.26± 0.49 a	51.14± 0.27 a	50.94 ± 0.18 a	50.79 ± 0.10 a	50.35 ± 0.18 A	50.90 ± 0.18 A
Average	51.24± 0.50 A	50.93± 0.27 A	50.54 ± 0.18 B	50.13± 0.10 C	49.44 ± 0.18 D	

TABLE 2: Effect of coating treatment and storage periods on egg weight (g) means ±SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2 ; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.
Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.
CMC, Carboxymethyl Cellulose; SE, Standard Error

Quality characteristics of eggs

Table 3 shows the effect of coating treatments for table eggs and storage at a temperature of $8^{o}C$ (in the refrigerator) on the average albumen high. No significant differences were observed among the six treatments in the high of albumen, and the values of egg albumen high ranged between 7.13 and 7.17 mm after 1 day of storage in the refrigerator, and the rates continued with increasing the storage period to 14 days, the values remained close, but increasing the storage period to 28 days showed significant differences ($P < 0.05$). The first treatment (control) record the lowest values (7.01 and 6.90 mm), while the differences were not significant between the other five treatments, which are the different egg-coating treatments, and the situation continued with increasing the storage period to 42 days, despite a slight decrease in the rates of albumen high for all treatments, and when increasing the storage period in the refrigerator to 56 days, the egg coating treatments with nanomaterials and nanocomposites with carboxymethyl cellulose, which are the third, fourth, and fifth treatments. The sixth treatment recorded the highest values without any significant difference between them, while the values decreased in the second treatment, which is coating eggs with carboxymethyl cellulose, with a significant difference ($P < 0.05$). The control recorded the lowest egg albumen values when stored in the refrigerator. The overall effect of the treatments indicated that the third, fourth, fifth, and sixth treatments were significantly ($P < 0.05$) superior to the second treatment, which in turn was superior to the first treatment. As for the effect of storage periods, the statistical analysis indicated that the highest values for the increase in egg albumen were recorded after 1 day of storage, with a significant difference ($P < 0.05$) from the storage periods of 14, 28, 42, and 56 days in the refrigerator.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	7.13± 0.15 a	7.01± 0.15 a	6.90 ± 0.09 b	6.11 ± 0.09 b	5.51 ± 0.36 c	6.32 ± 0.36 C
T2	7.12 ± 0.26 a	7.09 ± 0.26 a	7.02± 0.13 a	6.65 ± 0.13 a	6.14 ± 0.23 b	6.80 ± 0.23 B
T3	7.15 ± 0.42 a	7.10± 0.42 a	7.06± 0.25 a	6.77 ± 0.25 a	6.58 ± 0.08 a	6.93 ± 0.08 A
T4	7.17 ± 0.45 a	7.12 ± 0.45 a	7.07 ± 0.57 a	6.76 ± 0.57 a	6.55 ± 0.35 a	6.93 ± 0.35 A
T5	7.13 ± 0.32 a	7.10 ± 0.32 a	7.06 ± 0.32 a	6.78 ± 0.32 a	6.59± 0.31 a	6.93± 0.31 A
T6	7.16 ± 0.22 a	7.11 ± 0.22 a	7.08 ± 0.28 a	6.75 ± 0.28 a	6.57 ± 0.22 a	6.93 ± 0.22 A
Average	7.14 ± 0.33 A	7.09 ± 0.25 B	7.03 ± 0.18 C	6.64 ± 0.36 D	6.32 ± 0.22 E	

TABLE 3: Effect of coating treatment and storage periods on egg albumen high (mm) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

As shown in Table *4*, there were no significant differences between the six coating treatments regarding the Haugh unit value of the egg, with values ranging between 90.18 and 90.23 after 1 day of storage in the refrigerator. The Haugh unit continued with increasing the storage period to 14 days, and the rates remained close to each other, but extending the storage period to 48 days, significant differences appeared ($P < 0.05$), so that the first treatment (control) recorded the lowest values, reaching 85.01 and 76.70, respectively, while the differences were not significant between the other five treatments, which are egg coating treatments, and the situation continued with increasing the storage period to 42 days, despite a slight decrease in the Haugh unit values for all treatments. When the storage period in the refrigerator increased to 56 days, the egg coating treatments with nanomaterials and carboxymethyl cellulose, which are the third, fourth, fifth and sixth treatments, recorded the highest values ranged between 78.01 and 78.18, without significant difference between them, as the values decreased in the second treatment, which is coating eggs with carboxymethyl cellulose alone, significantly decreased ($P < 0.05$) to 75.51 and the control treatment recorded the lowest Haugh unit values, which reached 72.47 after storing it in the refrigerator for 56 days. The overall effect of the treatments indicated that the sixth and fourth treatments were significantly superior ($P < 0.05$) to the rest of the treatments, followed by the fifth and third treatments, with a significant difference ($P < 0.05$) over the second treatment, which in turn outperformed the first treatment. As for the effect of the storage periods, the results of the statistical analysis indicated that the highest Haugh unit values were recorded for eggs after 1 day of storage, reaching 90.62, and the values decreased significantly ($P < 0.05$) after storing it in the refrigerator to 14, 28, 42, and 56 days.

Treatment s	Storage (day)					Average	
	1	14	28	42	56		
T1	90.21 ± 0.76 a	88.20 ± 0.61 a	85.01 ± 1.49 c	76.70 ± 0.49 c	72.47± 0.89 c	82.51 ± 0.47 C	
T2	90.23 ± 0.0.30 a	88.58 ± 0.13 a	85.42 ± 0.52 b	80.41 ± 0.62 b	75.51 ± 1.17 b	84.03 ± 0.34 B	
T3	90.21±0.57 a	88.64 ± 0.74 a	86.44 ± 0.37 a	83.50 ± 1.77 a	78.01 ± 2.06 a	85.36± 0.39 A	
T4	90.18 ± 0.59 a	88.57 ± 0.46 a	86.50 ± 0.11 a	83.41 ± 1.54 a	78.14 ± 1.13 a	85.36 ± 0.55 A	
T5	90.19 ± 0.14 a	88.66 ± 0.43 a	86.47 ± 0.09 a	83.79± 0.64 a	78.07± 1.02 a	85.43± 0.37 A	
T6	90.20± 0.35 a	88.59 ± 0.46 a	86.54 ± 0.34 a	83.73 ± 1.06 a	78.18 ± 0.42 a	85.45± 0.27 A	
Average	90.20± 0.21 A	88.54 ±0.19 B	86.06 ± 0.27 C	81.92 ± 0.67 E	76.73 ± 0.52 F		

TABLE 4: Effect of coating treatment and storage periods on Haugh unit means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.
Different letters among columns revealed significant differences ($P < 0.05$) between treatments.
Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.
CMC, Carboxymethyl Cellulose; SE, Standard Error

Table 5 shows the effect of coating treatments for table eggs and storage at a 8°C (refrigerator) on the average yolk height of table egg, as no significant differences were found among the six treatments in terms of yolk height after storage for 1 day. The rates continued without significant differences up to 14 days of storage in the refrigerator, but increasing the storage period to 28 days showed a significant superiority ($P < 0.05$) for the third, fourth, fifth, and sixth treatments, with a significant difference from the second treatment, which recorded lower values, and which in turn significantly ($P < 0.05$) outperformed the first treatment (control), which recorded the lowest value for yolk height, reaching 17.66 mm. This trend persisted at 42 and 56 days of storage, with the third, fourth, fifth, and sixth treatments maintaining their significant superiority ($P < 0.05$) for the third, fourth, fifth, and sixth coating treatments over the second and first treatments, without a significant difference between them. The overall effect of the different egg coating treatments indicated a significant superiority ($P < 0.05$) of the third, fourth, fifth, and sixth treatments over the second treatment, which in turn significantly ($P < 0.05$) over the first treatment. The statistical analysis also indicated a significant effect ($P < 0.05$) of the storage periods, as the first period, after 1 day of storage, recorded the highest values, reaching 18.49 mm for yolk height values, with a significant difference from 14, 28, 42, and 56 days of storage in the refrigerator, which reached respectively.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	18.51 ± 0.38 a	18.26 ± 0.35 a	17.66 ± 0.35 c	16.55 ± 0.35 c	13.38 ± 0.20 c	16.87± 0.20 C
T2	18.49 ± 0.31 a	18.31± 0.28 a	17.91± 0.28 b	17.04± 0.28 b	15.97 ± 0.24 b	17.54 ± 0.24 B
T3	18.50 ± 0.23 a	18.42 ± 0.33 a	18.10 ± 0.33 a	18.37 ± 0.33 a	16.85 ± 0.23 a	18.04± 0.23 A
T4	18.48 ± 0.19 a	18.43 ± 0.23 a	18.07 ± 0.23 a	18.39 ± 0.23 a	16.88 ± 0.24 a	18.05 ± 0.24 A
T5	18.50 ± 0.29 a	18.42 ± 0.21 a	18.09 ± 0.21 a	18.36 ± 0.21 a	16.86 ± 0.46 a	18.05 ± 0.46 A
T6	18.49 ± 0.36 a	18.40 ± 0.42 a	18.05 ± 0.42 a	18.39 ± 0.42 a	16.87 ± 0.22 a	18.04 ± 0.22 A
Average	18.50 ± 0.36 A	18.36 ± 0.42 B	17.98 ± 0.42 C	17.85 ± 0.42 D	16.47 ± 0.22 E	

TABLE 5: Effect of coating treatment and storage periods on egg yolk high (mm) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P <0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table *6* shows the effect of table egg coating treatments and storage at refrigerator temperature on egg yolk diameter, where it was found that there were no significant differences between the different table egg coating treatments and the control after 1 day of refrigerator storage. Also, no significant differences appeared between the six different treatments up to 14 days, but increasing the storage period to 28 days showed a significant superiority ($P < 0.05$) of the five table egg-coating treatments, the second, third, fourth, fifth and sixth treatments compared with first treatment, with a significant difference. As the storage period increased to 42 and 56 days, the third, fourth, fifth, and sixth table egg treatments significantly ($P < 0.05$) outperformed the second treatment, with a significant difference in the rates of yolk diameter, while the second treatment significantly outperformed the control group. The first treatment (control) recorded the largest (least desirable) yolk diameter. The results of the statistical analysis indicated a significant effect ($P < 0.05$) of the treatment, as the control treatment resulted in the largest yolk diameter values, followed by the second treatment, while the third, fourth, fifth, and sixth treatments recorded the lowest yolk diameter values, which were the best. Also, the statistical analysis indicated that the best yolk diameter, which was the lowest value, was recorded after one day of storage for all six coating treatments, with values increasing significantly ($P < 0.05$) after 14, 28, 42, and 56 days of storage, indicating an increase in yolk diameter and a deterioration in quality with increasing storage time in the refrigerator.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	34.44 ± 0.68 a	34.47 ± 0.68 a	35.55 ± 0.20 a	36.27 ± 0.20 a	37.96 ± 0.43 a	35.74 ± 0.43 A
T2	34.45 ± 0.32 a	34.47 ± 0.32 a	34.51 ± 0.37 b	34.90 ± 0.37 b	36.18 ± 0.32 b	34.90 ± 0.32 B
T3	34.43 ± 0.29 a	34.46 ± 0.29 a	34.48 ± 0.45 b	34.74 ± 0.45 c	35.33 ± 0.42 c	34.68 ± 0.42 C
T4	34.46 ± 0.54 a	34.46 ± 0.54 a	34.49 ± 0.33 b	34.76 ± 0.33 c	35.34 ± 0.54 c	34.69 ± 0.54 C
T5	34.43 ± 0.85 a	34.45 ± 0.85 a	34.49 ± 0.39 b	34.75 ± 0.39 c	35.36 ± 0.22 c	34.70 ± 0.22 C
T6	34.45 ± 0.79 a	34.46 ± 0.79 a	34.48 ± 0.41 b	34.76 ± 0.41 c	35.35 ± 0.38 c	34.69 ± 0.38 C
Average	18.50 ± 0.36 A	18.36 ± 0.42 B	17.98 ± 0.42 C	17.85 ± 0.42 D	16.47 ± 0.22 E	

TABLE 6: Effect of coating treatment and storage periods on egg yolk diameter (mm) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table 7 shows the effect of table egg coating treatments and storage at refrigerator temperature on the yolk index table eggs. No statistically significant differences were found between the yolk index values of the six different treatments up to 14 days of storage. With increasing the storage period at refrigerator temperature to 28 days, significantly outperformed ($P < 0.05$) the control group, which recorded the lowest values. When increasing the storage period to 42 and 56 days, we found that the table egg coating treatments with nanocomposites and CMC, which are the third, fourth, fifth, and sixth treatments, recorded the best values with a significant difference ($P < 0.05$) over the second treatment, which is coating table eggs with CMC alone, which in turn outperformed the first control treatment, which recorded the lowest values. The overall effect of the treatments indicated that the third, fourth, fifth, and sixth treatments significantly outperformed the second treatment ($P < 0.05$), which in turn significantly outperformed ($P < 0.05$) control treatment, and the results of the statistical analysis indicated that the effect of storage periods was significant ($P < 0.05$), as the storage period after 1 day recorded the best values with a significant difference ($P < 0.05$) from the rest of the storage periods, which are 14, 28, 42 and 56 days, and the differences were significant between the different storage periods.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	0.50 ± 0.02 a	0.50 ± 0.01 a	0.48 ± 0.01 b	0.46 ± 0.01 c	0.43± 0.00 c	0.47 ± 0.00 C
T2	0.50 ± 0.02 a	0.50 ± 0.02 a	0.49 ± 0.01 a	0.48 ± 0.01 b	0.45 ± 0.00 b	0.48 ± 0.01 B
T3	0.50 ± 0.01 a	0.50 ± 0.01 a	0.49 ± 0.01 a	0.49 ± 0.01 a	0.48 ± 0.00 a	0.49 ± 0.00 A
T4	0.50 ± 0.01 a	0.50 ± 0.01 a	0.49 ± 0.01 a	0.49 ± 0.01 a	0.48 ± 0.01 a	0.49 ± 0.01 A
T5	0.50 ± 0.01 a	0.50 ± 0.01 a	0.49 ± 0.01 a	0.49± 0.01 a	0.48± 0.01 a	0.49± 0.01 A
T6	0.50± 0.01 a	0.50 ± 0.01 a	0.49 ± 0.01 a	0.49 ± 0.01 a	0.48 ± 0.01 a	0.49± 0.01 A
Average	0.50± 0.01 A	0.50 ±0.01 B	0.49 ± 0.01 C	0.49 ± 0.01 D	0.47 ± 0.01 E	

TABLE 7: Effect of coating treatment and storage periods on yolk index means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table *8* shows the effect of coating egg treatments and storage at refrigerator temperature on average eggshell thickness. At the start of storage, the second, third, fourth, fifth, and sixth different egg coating treatments contributed to a significant increase in eggshell thickness values ($P < 0.05$) compared to the control treatment, which recorded the lowest values immediately after treatment. Shell thickness values in the different egg coating treatments continued to be significantly superior ($P < 0.05$) to the control treatment with an increase in the storage period at refrigerator temperature to 14, 28, 42,and 56 days. The same table showed that the nanocomposite and CMC combinations (treatments 3, 4, 5, and 6) resulted in significantly higher overall eggshell thickness values than the second treatment, with a significant difference, which in turn recorded a higher shell thickness value than the control. The same table also showed an effect of storage periods, as they reached the highest values immediately after treatment, while the differences were not significant for storage after 14, 28, and 42 days. Significant differences ($P < 0.05$) appear again when stored to 56 days.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	0.41 ± 0.01 b	0.41 ± 0.01 b	0.41 ± 0.00 b	0.41 ± 0.01 b	0.41 ± 0.00 b	0.41 ± 0.00 C
T2	0.49 ± 0.00 a	0.48± 0.00 a	0.48 ± 0.00 a	0.46 ± 0.01 a	0.45 ± 0.00 a	0.47 ± 0.00 B
T3	0.51± 0.01 a	0.50 ± 0.00 a	0.50 ± 0.00 a	0.50 ± 0.01 a	0.49 ± 0.01 a	0.50 ± 0.01 A
T4	0.51 ± 0.01 a	0.50 ± 0.00 a	0.50 ± 0.00 a	0.49 ± 0.00 a	0.49 ± 0.00 a	0.50 ± 0.00 A
T5	0.50 ± 0.01 a	0.49 ± 0.00 a	0.49 ± 0.00 a	0.49 ± 0.00 a	0.48 ± 0.00 a	0.49 ± 0.00 A
T6	0.51 ± 0.00 a	0.50 ± 0.00 a	0.50 ± 0.00 a	0.51 ± 0.00 a	0.49 ± 0.00 a	0.50 ± 0.00 A
Average	0.49 ± 0.00 A	0.48 ± 0.00 B	0.48 ± 0.00 B	0.48 ± 0.00 B	0.47 ± 0.00 C	

TABLE 8: Effect of coating treatment and storage periods on eggshell thickness (mm) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table 9 shows the effect of table egg coating treatments and storage at refrigerator temperature on the eggshell weight percentage. It is clear that the egg coating treatments, the second, third, fourth, fifth, and sixth treatments, were significantly superior ($P < 0.05$) to the control treatment in the shell weight percentage, and their values ranged with a significant difference from the control treatment, which recorded the lowest values and reached immediately after the treatments were carried out, and with it the storage period in the refrigerator increased to 14, 28, and 42 days. The different coating treatments continued to outperform the control treatment significantly ($P < 0.05$). The differences were not significant between the five different coating treatments, but increasing the storage period to 56 days indicated that the third, fourth, fifth, and sixth egg coating treatments were superior to the second treatment with a significant difference ($P < 0.05$), so that the first treatment recorded the lowest weight and the lowest weight percentage. The statistical analysis indicated that the overall effect of the treatments indicated the superiority of the five egg coating treatments, the second, third, fourth, fifth, and sixth, over the first treatment (control), with no significant differences observed among the coated groups. differences between them, and the percentage of shell weight in it, as the statistical analysis indicated, was an effect of the storage periods, as the percentage of shell weight for storage of 56 days recorded the highest values, with a significant difference ($P < 0.05$) from the periods of 42 and 28 days. Furthermore, the values on day 28 did not differ significantly from those recorded on day 14 or day 1.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	10.25 ± 0.01 b	10.37 ± 0.00 b	10.60 ± 0.00 b	11.50 ± 0.00 a	11.95 ± 0.01 a	10.93 ± 0.01 B
T2	11.18 ± 0.01 a	11.20 ± 0.00 a	11.20 ± 0.00 a	11.27 ± 0.00 b	11.30 ± 0.00 c	11.25 ± 0.00 A
T3	11.20± 0.00 a	11.20± 0.00 a	11.21± 0.00 a	11.22± 0.00 d	11.24 ± 0.00 c	11.21 ± 0.00 A
T4	11.21 ± 0.01 a	11.21 ± 0.00 a	11.20 ± 0.00 a	11.22 ± 0.00 d	11.23 ± 0.01 c	11.23 ± 0.01 A
T5	11.22 ± 0.01 a	11.22 ± 0.01 a	11.23 ± 0.01 a	11.24 ± 0.01 c	11.26 ± 0.00 c	11.21 ± 0.00 A
T6	11.20 ± 0.00 a	11.21 ± 0.00 a	11.22 ± 0.00 a	11.23 ± 0.00 c	11.25 ± 0.00 c	11.22 ± 0.00 A
Average	11.14 ± 0.05 C	11.15 ± 0.07 C	11.17 ± 0.12 C	11.25 ± 0.01 B	11.32 ± 0.35 A	

TABLE 9: Effect of coating treatment and storage periods on eggshell (%) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table 10 shows the effect of coating treatments for table eggs and storage at refrigerator temperature on the egg yolk weight percentage, no significant differences were observed in the yolk weight percentage values for the six treatments under study, and their values ranged between 30.17 to 30.22%. The storage period continued to 42 and 56 days, the control treatment recorded significantly higher values ($P < 0.05$) compared to all other treatments in the yolk weight percentage, followed by the second treatment, which recorded lower values for the analysis of the third, fourth, fifth, and sixth treatments in the yolk weight percentage values, and the differences were not significant among them. The results of the statistical analysis indicated a significant effect ($P < 0.05$) for the total treatments, as the first treatment recorded the highest values for the yolk weight percentage. This was followed by the second treatment. while the third, fourth, fifth, and sixth treatments recorded the lowest yolk weight percentages. It was found that the storage period of 56 days recorded the highest yolk weight percentage, reaching 30.57%, with a significant difference from the storage periods of 42, 28, 14, and 1 day, which reached 30.44%, 30.39%, 30.30%, and 30.19%, respectively.

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Average	Storage (day)					Average
	1	14	28	42	56	
T1	30.22 ± 0.01 a	30.28 ± 0.01 a	31.38 ± 0.00 a	32.55 ± 0.00 a	32.95 ± 0.01 a	31.48 ± 0.01 A
T2	30.18 ± 0.01 a	30.27 ± 0.08 a	30.32 ± 0.01 b	30.39 ± 0.01 b	30.50 ± 0.01 b	30.33 ± 0.01 B
T3	30.19 ± 0.02 a	30.25 ± 0.00 a	30.29 ± 0.01 b	30.26 ± 0.01 c	30.38 ± 0.00 c	31.37 ± 0.00 A
T4	30.20 ± 1.01 a	30.34 ± 0.04 a	30.30 ± 0.01 b	30.27 ± 0.01 c	30.39 ± 0.01 c	30.30 ± 0.01 C
T5	30.17 ± 0.00 a	30.21 ± 0.00 a	30.31 ± 0.01 b	30.26 ± 0.01 c	30.37 ± 0.01 c	30.26 ± 0.01 C
T6	30.18 ± 0.05 a	30.24 ± 0.00 a	30.27 ± 0.01 b	30.26 ± 0.01 c	30.37 ± 0.01 c	30.26 ± 0.01 C
Average	18.51 ± 0.36 A	17.69 ± 0.42 B	16.27 ± 0.22 C	15.06 ± 0.24 D	13.31 ± 0.14 E	

TABLE 10: Effect of coating treatment and storage periods on egg yolk (%) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table *11* shows that the percentage of egg albumen was significantly higher ($P < 0.05$) in the first treatment (control), reaching 59.53% after 1-day storage, with a significant difference from the second, third, fourth, fifth, and sixth egg coating treatments, which did not differ significantly from one another, recording values of 58.64%, 58.61%, 58.59%, 58.61%, and 58.59%, respectively. When the storage period extended to 14 days, the percentage of egg albumen began to decrease in the control treatment, reaching 59.13%, although it remained significantly higher ($P < 0.05$) than the coated groups. However, this trend reversed as the storage period extended to 42 and 56 days. At these later stages, the third, fourth, fifth, and sixth egg coating treatments recorded the highest values of the percentage of egg albumen, followed by the second treatment, with a significant difference from the first treatment, which recorded the lowest values. The statistical analysis indicated that the overall effect of the treatments indicated that the indicated that treatments 3, 4, 5, and 6 were significantly superior ($P < 0.05$) to treatment 2, which in turn significantly outperformed the control group, which in turn was superior to the first treatment.

Average	Storage (day)					Average
	1	14	28	42	56	
T1	59.53 ± 0.00 a	59.13 ± 0.01 a	58.05 ± 0.00 c	55.95 ± 0.01 d	55.10 ± 0.01 c	57.55 ± 0.01 C
T2	58.64 ± 0.01 b	58.46 ± 0.01 c	58.35 ± 0.00 b	58.01 ± 0.05 c	57.54 ± 0.01 b	58.20 ± 0.01 B
T3	58.61 ± 0.01 b	58.55 ± 0.00 b	58.54 ± 0.01 a	58.32 ± 0.01 a	58.03 ± 0.01 a	58.41 ± 0.01 A
T4	58.59 ± 0.01 b	58.55 ± 0.02 b	58.49 ± 0.00 a	58.32 ± 0.02 a	58.02 ± 0.03 a	58.39 ± 0.01 AB
T5	58.61 ± 0.01 b	58.57 ± 0.04 b	58.47 ± 0.01 a	58.28 ± 0.00 b	58.07 ± 0.01 a	58.40 ± 0.01 AB
T6	58.62 ± 0.01 b	58.55 ± 0.04 b	58.50 ± 0.01 a	58.31 ± 0.00 b	08.58 ± 0.01 a	58.51± 0.02 A
Average	58.78 ± 0.01 A	58.63 ± 0.05 B	58.39 ± 0.01 C	58.06 ± 0.01 D	57.79 ± 0.02 E	

TABLE 11: Effect of coating treatment and storage periods on egg albumen (%) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table *12* shows the effect of coating egg treatments and storage on total bacterial count on the eggshell surface during storage at refrigerator temperature. Different coating treatments contributed to reducing the total bacterial count on the shell surface. The first treatment recorded the highest total bacterial count, reaching 3.48 log no./egg, followed by the second treatment, which recorded a total bacterial count of 3.25 log no./egg. However, there were no statistically significant differences between the third, fourth, fifth, and sixth treatments, which recorded the lowest values with a significant difference ($P < 0.05$) compared to the rest of the treatments after 1 day of storage. With increasing storage duration to 28, 42, and 56 days, the third and fifth nanoparticles coating treatments contributed to recording the lowest values of total bacteria on the eggshell surface with a significant difference ($P < 0.05$) compared to the rest of the treatments. Statistical analysis indicated an overall effect of treatment, as the third, fourth, fifth, and sixth egg coating treatments recorded the lowest total bacterial count, with a significant difference ($P < 0.05$) from the second treatment, which in turn outperformed the first treatment. The total bacterial count increased with increasing storage time, and the highest bacterial count was recorded after 56 days.

The overall egg coating treatment effect indicated that treatments 3 and 5 significantly ($P < 0.05$) outperformed the remaining treatments in reducing total bacterial counts, followed by treatments 4 and 6, followed by treatment 2, with treatment 1 recording the highest count. Statistical analysis also showed an effect of storage periods, with bacterial counts increasing significantly ($P < 0.05$) as the storage period increased from 1 day to 14, 28, 42, and 56 days. The 56-day storage period recorded the highest total bacterial count on the eggshell surface (4.31 log no./egg).

Average	Storage (day)					Average
	1	14	28	42	56	
T1	3.48 ± 0.55 a	4.12 ± 0.49 a	5.14 ± 0.51 a	5.57 ± 0.01 a	6.15 ± 0.26 a	4.65 ± 0.72 A
T2	3.25 ± 0.40 b	3.88 ± 0.26 b	4.05 ± 0.39 b	5.10 ± 0.37 b	5.75 ± 0.33 b	4.41 ± 0.28 B
T3	3.20 ± 0.19 c	3.40 ± 0.55 c	3.70 ± 0.09 d	4.04 ± 0.05 d	4.24 ± 0.2 d	3.74 ± 0.16 C
T4	3.22 ± 0.26 c	3.51 ± 0.19 c	3.83 ± 0.40 c	4.11 ± 0.37 c	4.42± 0.01 c	3.90 ± 0.01 C
T5	3.21 ± 0.01 c	3.53 ± 0.26 c	3.68 ± 0.01 d	4.01 ± 0.00 d	4.22 ± 0.12 d	3.68 ± 0.11 C
T6	3.20± 0.50 c	3.46 ± 0.10 c	3.76 ± 0.18 c	4.18 ± 0.27 c	4.39 ± 0.18 c	3.67 ± 0.07 C
Average	3.25 ± 0.21 D	3.48 ± 0.18 D	4.02 ± 0.23 BC	4.50 ± 0.21 B	4.86 ± 0.19 A	

TABLE 12: Effect of coating treatment and storage periods on total bacterial count (log no./egg) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

Table *13* show the effect of table egg coating treatments and storage at refrigerator temperature on the total coliform bacteria counts on the eggshell surface. Egg coating treatments contributed to a significant ($P < 0.05$) reduction in the counts of this group of bacteria on the eggshell surface. The best treatments were the third and fifth treatments, as they recorded the lowest values for the total coliform bacteria counts (2.05 and 2.04 log no./egg) immediately after the treatment, with a significant difference ($P < 0.05$) from the rest of the treatments. The fourth and sixth treatments followed (2.17 and 2.18 log no./egg), with a significant difference ($P < 0.05$) from the second treatment (2.26 log no./egg). The latter outperformed the first treatment significantly, so that the first control treatment recorded the highest values for the total coliform bacteria counts (3.05 log no./egg). The situation continued with the increase in the storage period in the refrigerator, as the number of bacteria in the first treatment (control) continued to be significantly superior ($P < 0.05$) to the rest of the treatments, with the storage period increasing to 14, 28, 42, and 56 days, followed by the second treatment, then the fourth and sixth treatments, with the third and fifth treatments recording the lowest total coliform counts. The overall effect of the treatment also indicated that the third and fifth treatments were significantly superior ($P < 0.05$) to the rest of the treatments in reducing the number of coliform bacteria, followed by the fourth and sixth treatments, then the second treatment, and the first treatment recording the highest count. The statistical analysis also showed an effect of the storage periods, as the number of bacteria increased significantly ($P < 0.05$) with the increase in the storage period from one to 14, 28, 42, and 56 days, with the 56-day storage period recording the highest values for the total number of coliform bacteria on the surface of the eggshell (4.31 log no./egg).

Average	Storage (day)					Average
	1	14	28	42	56	
T1	3.05 ± 0.55 a	3.71 ± 0.49 a	4.25 ± 0.51 a	4.91 ± 1.02 a	5.56 ± 0.26 a	4.30 ± 0.72 A
T2	2.26 ± 0.40 b	2.47 ± 0.26 b	2.95 ± 0.39 b	3.63 ± 0.37 b	4.40 ± 0.33 b	3.14 ± 0.28 B
T3	2.05 ± 0.55 d	2.12 ± 0.19 d	2.22 ± 0.09 d	2.85± 0.05 d	3.52 ± 0.2 d	2.55 ± 0.16 D
T4	2.17 ± 0.40 c	2.26 ± 0.26 c	2.38 ± 0.19 c	3.01 ± 0.37 c	3.74 ± 0.36 c	2.71 ± 0.22 C
T5	2.04 ± 0.55 d	2.11 ± 0.1.8 d	2.19 ± 1.22 d	2.76 ± 0.10 e	3.51 ± 0.12 d	2.50± 0.11 D
T6	2.18 ± 0.50 c	2.26 ± 0.27 c	2.33 ± 0.18 c	3.08 ± 0.10 c	3.79 ± 0.18 c	2.71 ± 0.07 C
Average	2.29 ± 0.21 E	2.48 ± 0.18 D	2.72 ± 0.23 C	3.37 ± 0.21 B	4.08 ± 0.19 A	

TABLE 13: Effect of coating treatment and storage periods on total coliform count (log no./egg) means ± SE.

T1: Uncoated eggs as a control group; T2: Eggs coated with CMC; T3: Eggs coated with SiO_2; T4: Eggs coated with CMC + SiO_2; T5: Eggs coated with TiO_2; T6: Eggs coated with CMC + TiO_2.

Different letters among columns revealed significant differences ($P < 0.05$) between treatments.

Different letters among rows revealed significant differences ($P < 0.05$) between storage periods.

CMC, Carboxymethyl Cellulose; SE, Standard Error

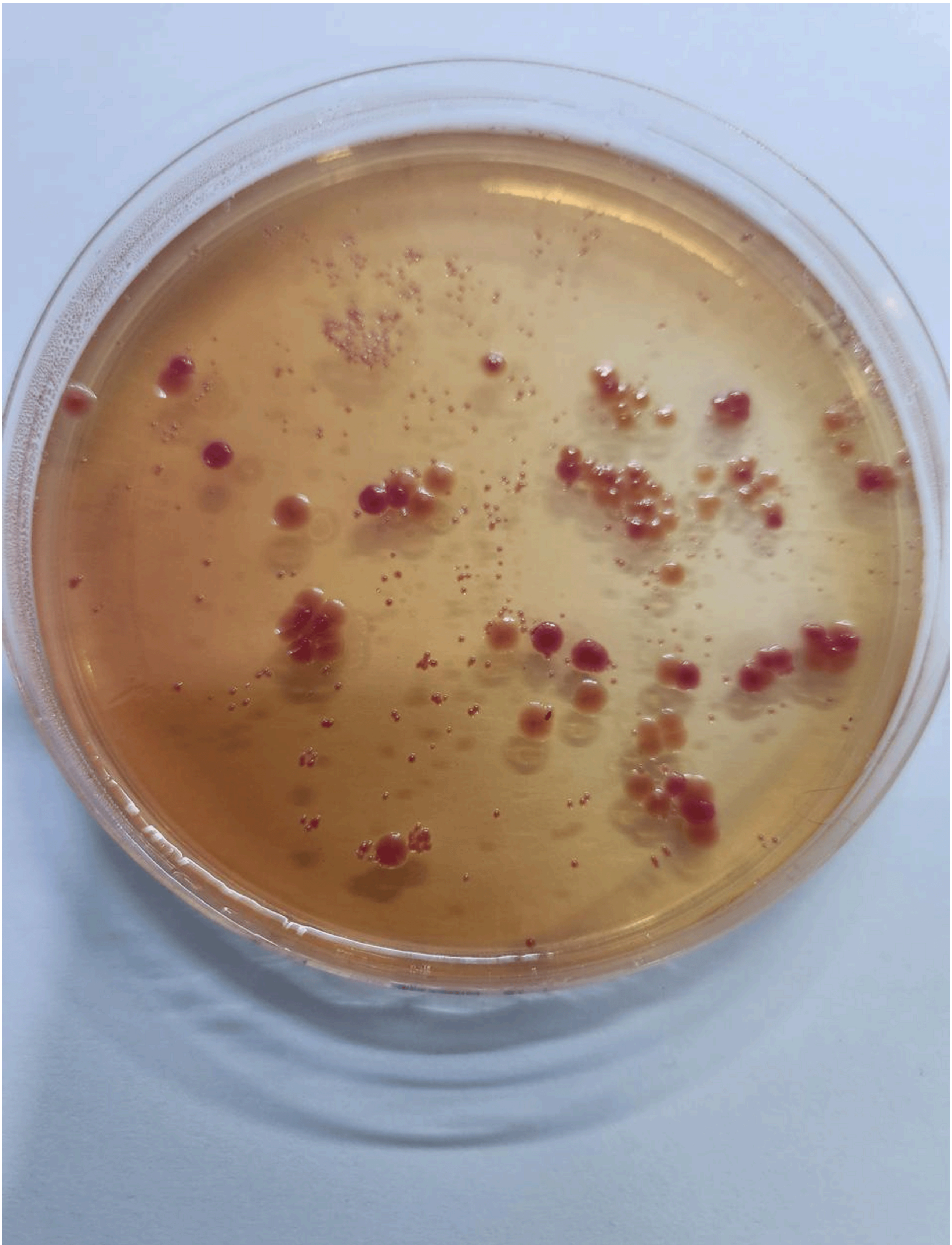

FIGURE 1: Total coliform count (MacConkey agar) in pour plate method.

MacConkey agar Petri dishes, red color media.

The results of this study indicate that the processes of coating table eggs at the beginning of the experiment contributed to a significant increase in egg weight compared to control treatment eggs, and this is due to the formation of a relatively thick layer that covered the eggshell [10-12]. When the storage period advanced, there was a decrease in eggs weights for all treatments, but the percentage of decrease was significantly high in the eggs of the control treatment, this is due to the role of coating in preventing the exit of moisture and CO_2 gas from the inside of the egg to the outer environment through the pores around shell of egg. In this study, coating processes contributed to preserving moisture and CO_2 gas inside the egg, so egg deterioration will decrease [1,3].

The deterioration of control eggs continued after storage for 2 and 4 weeks in refrigerator, as the height of the yolk and the index of the yolk and the height of the albumen decreased, and the diameter of the yolk increased with a significant ($P < 0.05$) difference from the rest of the coating treatments, and this is due to the presence of open pores in the eggshell, which are naturally present [4], and which naturally allow the exit of moisture and CO_2 gas, which leads to a decrease in egg pH and causing to deterioration in the quality of the egg white and an increase in the liquefaction of the gelatinous texture of the albumen, and this will release and migration of bounded water from the albumen to the egg yolk with much greater extent than what happened in coated egg which preserved moisture and CO_2 gas and did not deteriorate the gelatinous texture of the albumen [23,30].

The use of nanoparticles of TiO_2, SiO_2, and their composite with CMC in our study are green technology for preserving food and table eggs for 8 weeks. Significant differences were observed in the values of the Haugh unit between fresh, uncoated, and coated eggs. After 2 weeks, the best result was for the eggs coated in chitosan with nanocomposites. This study also showed that these shells acted as a protective barrier to maintain the internal quality of fresh eggs at a higher level than uncoated eggs [20]. This is consistent with the results of our study when using shells of a CMC mixture with silica and titanium nanoparticles.

Table eggs produced by layer chicken farms pass through several different marketing channels before reaching the consumer, including transportation, storage, and preservation at different temperatures, as well as hand-handling when displayed in retail stores. This increases the bacterial count on eggshells. Jabalera et al. [33] indicated that the average total bacterial count on eggshells displayed in stores reached 150×10^2 bacteria/egg, compared to the average total bacterial count on eggshells produced in layer chicken farms, which was 91×10^2 bacteria/egg during the summer season. Hsu et al. [34] found significant variations in the level of microbial contamination of table eggs displayed in wholesale and retail stores in different areas of Taiwan, depending on the temperature and display method. The use of efficient refrigerators helps limit the growth of microorganisms compared to selling eggs on sidewalks and in the open. The bacterial isolates from different markets of Baghdad city were high in cracked eggshells and egg contents (46% and 44%), these isolated include *Escherichia coli*, *Staphylococcus, Enterococcus faecalis, Enterobacter,* and *Pseudomonas* [35]. The process of coating eggs with refrigerator storage contributed to a decrease in the total bacterial count and the total coliform count on the surface of the eggs after storage for 1, 2, 4, and 8 weeks compared to unwrapped eggs [23]. Statistical analysis showed that coating with CMC and Agar, the latter being the best for preserving the qualitative characteristics of the egg, did not allow for a significant increase in the growth of microorganisms on the surface of the shell. This is consistent with the results of our study, which stated that the used coating did not contribute to an increase in the total bacterial count and the coliform count [36]. Rather, the treatments of using coats containing silica and titanium nanoparticles contributed to a significant reduction in these bacterial groups on the surface of the treated eggshell, as these compounds have a negative effect on the activity and growth of bacteria and microorganisms in general. It has been experimentally proven that modifying some coating with oxide nanoparticles such as titanium silica, zinc, and copper have been used in the compose of protective and effective egg coating materials that extend the shelf life of table eggs and prevent the growth and spread of bacterial contamination, especially pathogenic bacteria. In addition, some casings are virus-inhibiting [37].

Conclusions

In conclusion, the use of coating materials for table eggs including CMC combined with titanium oxide (TiO_2) and silica oxide (SiO_2) nanoparticles proved to be highly effective in improving egg quality and extending shelf life when storage at refrigerator temperature (8°C), which maintained superior egg weight, interior egg quality, including albumen high, Haugh Unit, yolk Index, and optimal proportions of egg components (yolk and albumen). These treatments significantly outperformed coating with CMC alone (T2) and the uncoated control (T1), which showed the lowest values. Furthermore, bacterial counts revealed a significant reduction in total bacterial counts and coliform counts in the first day of coating and throughout storage periods, with T3 and T5 having the lowest bacterial counts, followed by T4 and T6. In contrast, T1 consistently recorded the highest bacterial counts. During storage, uncoated eggs (T1) showed rapid bacterial growth, whereas coated eggs, especially those treated with CMC + TiO_2 (T6) and CMC + SiO_2 (T4), maintained significantly lower bacterial counts. This nano coating is a green technology representing a promising approach for table egg preservation.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Plant subjects: All authors have confirmed that this study did not involve any herbarium specimen. **Human subjects:** All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statements

The datasets (and/or code) supporting this study are available from the corresponding author upon reasonable request.

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