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Preserving the Internal Quality of Quail Eggs Using a Corn Starch-Based Coating Combined with Basil Essential Oil

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Abstract: The objective of the study is to evaluate a new proposal for a coating based on corn starch (CS) enriched with basil essential oil (BEO) to overcome the rapid deterioration of quail eggs under nonrefrigerated conditions. One hundred and seventy-one quail eggs were divided into treatments of uncoated eggs (control), eggs coated with CS, and eggs coated with CS/BEO, and analyzed over four weeks at room temperature. The CS/BEO coating reduced the growth of total aerobic mesophilic bacteria, Enterobacteriaceae, molds, and yeasts on the surface of eggshells to $<2 \log_{10}$ CFU/mL compared to the control treatment at week four storage. The average Haugh unit (HU) of the four weeks of storage of the CS/BEO treatment was notably higher compared to the control. There was no significant difference between the sensory parameter scores of coated eggs and control treatment. Based on the findings, the CS/BEO coating can be used to mitigate the contamination of quail eggs and preserve their internal quality when stored in an environment without temperature and humidity control.

Keywords: consumer acceptability; food safety; microbiological quality

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1. Introduction

A proper protocol for processing eggs up to the point of sale keeps the eggs attractive to the consumer due to low soiling on the shell surface, reduced cracking, uniformity, and slower aging. The postlaying waste of eggs can be a result of not adopting efficient conservation methods during egg processing. This is often due to high costs of implementing chilling methods [1,2] or because synthetic preservatives are harmful to human and environmental health [3]. For quail eggs, under current conditions, edible, friendly, minimally toxic, financially viable, and potentially efficient strategies are suggested to reduce egg waste due to high temperatures and microbial proliferation [4–6].

Starch comes from vegetables like corn and is made up of an amylopectin portion and an amylose portion [7]. Corn starch (CS) is one of the preferred materials for making edible food coatings. This polysaccharide promotes the development of coatings that can provide powerful and selective barriers to the transfer of water and gases, in addition to ensuring a food with a pleasant visual appearance [8]. Essential oils can be homogenized in starch-based coating manufacturing solutions to improve their microstructure, as well as their physical and antimicrobial attributes [9].

Basil essential oil (BEO) is a liquid and volatile compound extracted from basil (*Ocimum basilicum* L.), an edible aromatic vegetable cultivated globally with versatile applicability in the food industry. Its application as an additive in edible hydrophilic films and coatings for food preservation is one of the current trends. Incorporating BEO in the starch-based coating makes it more efficient in delaying food ageing and reducing its microbial load [10]. There is no evidence from studies on the deposition of CS coating associated with BEO on quail eggs. As egg waste dictates the financial performance of the poultry chain, the quality of quail eggs must be prolonged with conservation practices. This action can allow the eggs to remain viable for consumption longer, ensuring a good financial return. This study evaluates a new proposal for a coating based on CS enriched with BEO to overcome the rapid deterioration of quail eggs under nonrefrigerated conditions.

2. Materials and Methods

The BEO (Phytoterápica®, Rio de Janeiro, Brazil) from basil leaves and flowers was obtained by steam distillation. The chemical composition of BEO was analyzed in duplicate using a gas chromatograph (GCMS-QP2010 SE, Shimadzu, Kyoto, Japan) equipped with a Quadrex capillary column (DB-5MS) (5% diphenyl dimethylsiloxane) (30 m $\times$ 0.25 mm, 0.25 μm film thickness, Agilent Technologies). Prior to analysis, 20 μL of BEO was diluted in HPLC grade dichloromethane (1:25). The sample was injected with a split ratio of 10 and a volume of 1 μL. The injector temperature was maintained at 240 °C, and the carrier gas was helium (99.999%) at a flow rate of 1 mL min^{-1}. The column oven temperature program was set at 60 °C and increased up to 246 °C at a rate of 3 °C min^{-1}, with an additional ten-minute constant hold, for a total run time of 72 min. The equipment was operated in electron impact ionization mode at 70 eV and scanned at a range of 35 to 500 m/z. The chemical composition of the essential oils was determined by comparing the mass spectra of oil components with the National Institute of Standards and Technology (NIST 14) library and Kovats index. The relative composition was calculated by dividing the peak area of each compound by the sum of all peak areas based on the Total Ion Chromatogram provided by Shimadzu GCMS Postrun Analysis Software. BEO presented estragole (60.98%) as the major compound (Table 1).

A preliminary duplicate assay using a 96-well plate demonstrated that BEO inhibited the growth of strains J96 (*Escherichia coli*; ATCC, Manassas, VA, USA) and SA23923 (*Staphylococcus aureus*; ATCC, Manassas, VA, USA) with a minimum inhibitory concentration of 100 mg/mL for *Escherichia coli* and 300 mg/mL for *Staphylococcus aureus* (Table 2). The concentration of 300 mg/mL was chosen to add to the coating, since only from this concentration did BEO show inhibition for two tested strains.

The CS/BEO coating was formulated (Table 3) for 40 min. CS (Bio Mundo, Brasília, Brazil), glycerol (Dinâmica, São Paulo, Brazil) and distilled water were mixed in a beaker using magnetic stirring for 30 min at 80 °C. After reducing the temperature of the solution to 40 °C, BEO was added, and the solution was stirred for another 10 min.

Table 1. Chemical composition of basil essential oil (BEO) by gas chromatography-mass spectrometry (GC-MS).

Retention Time	Kovats Index	Kovats Index Library	Area (%)	Name	% of Similarity
4.336	939	939	0.10	α-pinene	96
5.153	977	977	0.02	Sabinene	90
5.233	981	980	0.06	β-Pinene	95
5.320	984	978	0.01	1-octeno-3-ol	86
5.459	989	987	0.10	6-Methyl-5-heptene-2-one	93
5.537	992	992	0.08	β-Myrcene	92
6.052	1013	1013	0.01	δ-3-carene	89
6.438	1028	1028	0.30	o-Cymene	96
6.549	1032	1032	0.35	D-Limonene	95
6.620	1035	1031	0.63	1,8-cineole	96
7.106	1052	1052	0.06	(E)-β-ocimene	96
7.916	1077	1072	0.40	Cis-Linalool oxide (furanoid)	94
8.456	1092	1086	0.34	Trans-Linalool oxide (furanoid)	94
9.183	1113	1095	22.96	Linalool	98
9.755	1131	-	0.04	Plinol A	95
10.735	1158	1152	0.37	Menthona	96
10.865	1161	1162	0.06	Cis-p-3-menthona	89
11.220	1170	1165	0.33	Neomenthol	91
11.645	1180	1171	1.73	Menthol	97
13.380	1224	1213	60.98	Estragole	96
13.621	1230	-	0.11	(-)-trans-isopiperitenol	91
13.952	1239	1229	0.08	Geraniol	86
14.250	1246	1237	0.01	Pulegone	89
14.335	1248	1238	0.55	Neral	97
14.842	1260	1252	0.22	Anethole	94
14.947	1263	1265	0.21	Anisic aldehyde	90
15.515	1276	1267	0.75	Geranial	97
16.217	1291	1284	1.52	Anethole (E)	97
16.412	1295	1295	0.07	Mentyl acetate	92
18.127	1338	1338	0.03	δ-Elemene	92
18.638	1351	1352	0.03	a-cubebene	89
19.691	1375	1376	0.04	Copaene	92
20.256	1387	1383	0.08	Hexyl hexanoate	87
20.400	1391	1436	0.05	γ-Elemene	89
21.187	1409	1403	0.03	Methyl eugenol	89
21.458	1416	1419	0.28	(E) Caryophyllene	96
22.221	1436	1435	0.61	Trans-a-bergamotene	97
22.496	1443	1459	0.06	Sesquisabinene	94
23.121	1458	1458	0.16	(E)-β-farnesene	96
23.985	1478	1481	0.03	Germacrene D	92
25.182	1507	1505	0.11	β-Bisabolene	94
25.755	1522	1523	0.02	d-Cadinene	91
26.601	1544	1515	1.30	γ-Bisabolene	95
27.410	1565	1565	0.05	(E)-nerolidol	92
27.782	1574	1564	0.95	3-Methoxycinnamaldehyde	95
29.049	1605	1608	0.08	Humulene epoxide	91
31.954	1683	1684	0.02	Epi-α-bisabolol	92
53.630	2366	-	0.03	β-amyrin acetate derivative—oleanane type triterpene	91
53.916	2377	-	0.14	α-amyrin acetate derivate—oleane type triterpene	91
60.965	-	-	1.43	α-alpha-Amyrin acetate derivate (ursane type triterpene)	90
-			1.85	Unidentified	

Table 2. Minimum inhibitory concentration (MIC) of basil essential oil (BEO) against *Escherichia coli* and *Staphylococcus aureus*.

Bacterial Strains	BEO Concentration (mg/mL)				
	100	200	300	400	500
Escherichia coli	IN	IN	IN	IN	IN
Staphylococcus aureus	NI	NI	IN	IN	IN

IN, Inhibited the growth of the microorganism; NI, No inhibition of the growth of microorganisms.

Table 3. Formulation of corn starch coating with basil essential oil (CS/BEO).

Coating	CS (g)	BEO (g) *	Glycerol (g)	Distilled Water (mL)
CS	24	0	12	400
CS/BEO	24	4	12	400

* BEO diluted in Tween 80 to a desired concentration of 300 mg/mL.

Unwashed eggs from 24-week-old quails (*Coturnix coturnix japonica*), weighing an average of 10.93 ± 0.71 g, were used to evaluate egg coating use. The quail rearing shed had approximately one thousand quails, all in the laying phase. An optical classification was performed to identify unviable eggs for consumption regarding excessive dirt, breakage, and deformation. The coatings tested in this study were CS and CS/BEO. Three treatments were established, and each consisted of 57 eggs. In addition to the CS and CS/BEO treatments, a control group of uncoated eggs was used. Once the eggs were coated, they were adequately stored together with the uncoated eggs for four weeks at room temperature (average = 26.71 ± 1.11 °C and 65.15 ± 3.56% relative humidity) in a thoroughly sanitized experimental laboratory, simulating actual egg storage conditions in uncontrolled conditions. Temperature and humidity were monitored daily every 5 min using a HOBO data logger (Onset Computer Corp., Bourne, MA, USA). The practice of coating and drying the eggs followed the following protocol: immersion for 45 s and drying for three hours.

The internal quality characteristics of the eggs were evaluated over four weeks of storage, always at the same time, to compare the treatments (Table 4).

Table 4. Methods to measure the internal quality of quail eggs.

Parameters	Evaluation	Evaluation Equipment	Evaluation Day	Number of Eggs Evaluated */Treatment (Weekly)	Formula	Reference
Egg weight loss (EWL, %)	Initial (IEW) and final egg weight (FEW)	Analytical scale with 0.0001 g precision (Gehaka, São Paulo, São Paulo, Brazil)	From day 7 (weekly)	8	EWL = (IEW − FEW)/IEW × 100	-
Haugh unit (HU)	Albumen height (H) and egg weight (W)	Analytical scale and digital caliper with 0.001-mm precision (Mitutoyo, Suzano, São Paulo, Brazil)	From day 0 (weekly)	8	$HU = 100 \log (H + 7.57 - 1.7 W^{0.37})$	[11]
Yolk index (YI)	Yolk height (h) and yolk diameter (d)	Digital caliper	From day 0 (weekly)	8	YI = h/d	[12]
Albumen pH (ApH) and yolk pH (YpH)	ApH and YpH	Digital pH meter (Kasvi, Campina São José do Pinhais, Paraná, Brazil)	From day 0 (weekly)	8	-	-

* A total of 18 eggs had their internal qualities assessed on day 0 to determine initial egg quality.

In the fourth week of storage at room temperature, ten eggs from each treatment were cooked for 15 min, peeled, and placed in identified plastic trays for sensory analysis. Ten volunteer panellists from Federal Institute of Brasília, Campus Planaltina, Brasília, Brazil evaluated and scored the eggs. The panellists confirmed their participation in the sensory evaluation of the eggs after signing the Free and Informed Consent Form. One egg from each treatment was distributed blindly and randomly for each panellist. The score of each egg ranged from 1 (dislike immensely) to 9 (like significantly) according to color, aroma, odor, texture, taste, and general acceptability [13].

The shell and contents of the eggs were investigated in triplicate for the presence of total aerobic mesophilic bacteria, Enterobacteriaceae, molds, and yeasts in the fourth week of storage, adapting the microbiological methods of Wells et al. [14] and Figueiredo et al. [15]. A pool of three eggs was washed in a sterile bag with 60 mL of 0.1% peptone saline solution. These same eggs were individually broken, and 6 mL of the mixed content of each one of them was added to the same beaker containing 162 mL of 0.1% peptone saline solution. Shell wash water and homogenized egg content were serially diluted, except for coated eggs. Plate count agar was used for the enumeration of total aerobic mesophilic bacteria. Violet red bile glucose agar was used for the enumeration of Enterobacteriaceae. Potato dextrose agar was used for enumeration of molds and yeasts. Petri dishes inoculated with 1 mL of the final water rinse solutions or egg contents mixture were incubated at 36 °C for 48 h (bacteria count) or 29 °C for five days (mold and yeast count). Colonies were counted, and the total number of colonies on each plate was transformed to $\log_{10}$ CFU/mL.

A completely randomized design was used in the study. Data were statistically analyzed in SAS Studio University Edition software (SAS Inst. Inc., Cary, NC, USA). First, it investigated whether to normality. The analysis of variance was performed using PROC GLM. Tukey's test was used to compare treatment means. The significance level was 0.05. Nonparametric data were analyzed using the Kruskal-Wallis test from PROC NPAR1WAY.

Parameters were analyzed according to the following statistical model:

$$Yijk = \mu + di + wk + dwjk + eijk$$

where: μ: mean overall; di: effects of treatments; wk: effect of storage periods; dwjk: effect of the interaction between treatment and storage periods; eijk: random error.

3. Results and Discussion

Essential oils can achieve a significant share in the poultry industry and market in the future. The preservative and sanitizing function of essential oils [16–18] are two of their innumerable characteristics that stimulated studies on egg coatings, aiming to make them available for industrial application. In the present study, the CS/BEO coating was evaluated after application to quail eggs.

The CS/BEO coating reduced ($p < 0.05$) the growth of total aerobic mesophilic bacteria, Enterobacteriaceae, molds, and yeasts on the surface of eggshells to <2 $\log_{10}$ CFU/mL compared to the control treatment at week four storage (Table 5). Likewise, eggs treated with CS/BEO had on average 1.58 $\log_{10}$ CFU/mL less ($p < 0.05$) total aerobic mesophilic bacteria, Enterobacteriaceae, molds, and yeasts in their contents than eggs from the control treatment (Table 5). The microbial reductions observed by the CS coating without the addition of the antimicrobial compound (BEO) concerning the control treatment, for example, on the eggshells (Table 5), could be because the coating, in contact with the eggshells, promoted a physical occlusion for microbial agents [19], making it impossible for them to adhere and survive on the coated eggshells. The synergistic effect of CS with BEO appears to have successfully enhanced the antimicrobial effect of the CS/BEO coating. BEO may have contributed to the reduced permeability of the CS coating [20], which may have made coated eggshells an adverse environment for microbial penetration. Furthermore, when in contact with microorganisms, BEO can weaken the functions of the cell membrane, cytoplasm, enzymes, proteins, fatty acids, ions, and metabolites [21]. These results of this study agree with Oliveira et al. [22], who evaluated eggs coated with cassava starch added with essential oil of ginger, lemongrass, or lemon Tahiti, and with Oliveira et al. [6] evaluating eggs with rice flour supplemented with rosemary essential oil.

Table 5. Effect of corn starch coating plus basil essential oil (CS/BEO) on the count of total aerobic mesophilic bacteria, Enterobacteriaceae, molds, and yeasts in shells and contents of quail eggs in the fourth week of storage at room temperature [1].

Treatments	Eggshell		
	Total Aerobic Mesophilic Bacteria	Enterobacteriaceae	Molds and Yeasts
Control	3.14 ± 0.35 [a]	3.04 ± 0.28 [a]	3.07 ± 0.35 [a]
CS	2.39 ± 0.07 [b]	2.20 ± 0.12 [b]	2.31 ± 0.08 [b]
CS/BEO	1.43 ± 0.19 [c]	1.53 ± 0.25 [c]	1.87 ± 0.18 [b]
p value	0.0003	0.0006	0.0021
Treatments	**Egg Content**		
	Total Aerobic Mesophilic Bacteria	Enterobacteriaceae	Molds and Yeasts
Control	2.50 ± 0.14 [a]	3.10 ± 0.31 [a]	3.15 ± 0.27 [a]
CS	2.04 ± 0.09 [ab]	2.27 ± 0.09 [ab]	1.96 ± 0.54 [b]
CS/BEO	1.00 ± 0.86 [b]	1.27 ± 0.75 [b]	1.73 ± 0.23 [b]
p value	0.0269	0.0093	0.0074

[1] Data are expressed as mean (log_{10} CFU/mL) ± standard deviation of triplicate measurements. Different letters in the same column indicate significant differences among means ($p < 0.05$).

CS/BEO significantly inhibited ($p < 0.05$) weight loss from the third week of storage, reducing this loss by 2.36% compared to the control treatment (Table 6). In the fourth week, the difference between these treatments remained significant ($p < 0.05$), and the eggs treated with CS/BEO had a 3.23% lower weight loss than the control treatment eggs (Table 6). The low water vapor permeability of a coating will minimize evaporation of water content from the egg, influencing the rate of weight loss [23]. Therefore, it is hypothesized that this inhibition of egg weight loss resulted from the low water vapor permeability of CS/BEO, as this is a common feature of starch-based coatings incorporated with essential oils [20,24].

Table 6. Effect of corn starch coating plus basil essential oil (CS/BEO) on weight loss (EWL), Haugh unit (HU), yolk index (YI), albumen pH (ApH), and yolk pH (YpH) of quail eggs stored for four weeks at room temperature [1].

Treatment	EWL (%)				
	0 weeks	1 weeks	2 weeks	3 weeks	4 weeks
Control	-	2.15 ± 2.02 [B,a]	3.75 ± 2.95 [AB,a]	6.30 ± 2.61 [A,a]	7.12 ± 0.99 [A,a]
CS	-	2.40 ± 0.83 [B,a]	3.00 ± 0.69 [AB,a]	4.78 ± 1.47 [AB,ab]	5.13 ± 0.79 [A,ab]
CS/BEO	-	2.25 ± 0.95 [A,a]	2.94 ± 0.96 [A,a]	3.66 ± 1.09 [A,b]	3.89 ± 0.80 [A,b]
p value					
T			0.0002		
SP			<0.0001		
TxSP			0.0684		
Treatment	**HU (Egg grade *)**				
	0 weeks	1 weeks	2 weeks	3 weeks	4 weeks
Control	92.23 (AA) ± 4.21 [A,a]	85.73 (AA) ± 2.53 [B,a]	81.83 (AA) ± 2.78 [BC,a]	79.69 (AA) ± 3.79 [BC,a]	77.57 (AA) ± 3.27 [C,a]
CS	92.23 (AA) ± 4.21 [A,a]	87.57 (AA) ± 3.20 [AB,a]	85.95 (AA) ± 1.64 [B,a]	84.62 (AA) ± 1.89 [B,a]	77.95 (AA) ± 4.55 [C,a]
CS/BEO	92.23 (AA) ± 4.21 [A,a]	86.51 (AA) ± 2.39 [B,a]	86.27 (AA) ± 2.21 [B,a]	85.04 (AA) ± 2.36 [B,a]	81.74 (AA) ± 3.10 [B,a]
p value					
T			0.0016		
SP			<0.0001		
TxSP			0.0956		

Table 6. *Cont.*

Treatment	YI				
	0 weeks	1 weeks	2 weeks	3 weeks	4 weeks
Control	0.38 ± 0.03 ^{A,a}	0.29 ± 0.03 ^{B,a}	0.23 ± 0.02 ^{CD,a}	0.17 ± 0.02 ^{DE,b}	0.13 ± 0.01 ^{E,b}
CS	0.38 ± 0.03 ^{A,a}	0.28 ± 0.09 ^{B,a}	0.25 ± 0.02 ^{B,a}	0.18 ± 0.01 ^{C,ab}	0.15 ± 0.02 ^{C,ab}
CS/BEO	0.38 ± 0.03 ^{A,a}	0.33 ± 0.02 ^{B,a}	0.28 ± 0.02 ^{BC,a}	0.23 ± 0.04 ^{CD,a}	0.20 ± 0.04 ^{D,a}
p value					
T			<0.0001		
SP			<0.0001		
TxSP			0.0039		
Treatment	**ApH**				
	0 weeks	1 weeks	2 weeks	3 weeks	4 weeks
Control	9.43 ± 0.40 ^{B,a}	9.70 ± 0.05 ^{AB,a}	9.83 ± 0.22 ^{AB,a}	10.00 ± 0.40 ^{A,a}	10.02 ± 0.29 ^{A,a}
CS	9.43 ± 0.40 ^{B,a}	9.73 ± 0.13 ^{AB,a}	9.62 ± 0.14 ^{AB,a}	9.95 ± 0.33 ^{A,a}	9.76 ± 0.13 ^{A,a}
CS/BEO	9.43 ± 0.40 ^{A,a}	9.48 ± 0.35 ^{A,a}	9.50 ± 0.16 ^{A,a}	9.64 ± 0.0.37 ^{A,a}	9.60 ± 0.15 ^{A,a}
p value					
T			<0.0001		
SP			<0.0001		
TxSP			0.2099		
Treatment	**YpH**				
	0 weeks	1 weeks	2 weeks	3 weeks	4 weeks
Control	6.82 ± 0.33 ^{C,a}	7.14 ± 0.22 ^{BC,a}	7.41 ± 0.18 ^{AB,a}	7.70 ± 0.28 ^{A,a}	7.77 ± 0.14 ^{A,a}
CS	6.82 ± 0.33 ^{C,a}	7.15 ± 0.09 ^{BC,a}	7.19 ± 0.38 ^{BC,a}	7.70 ± 0.17 ^{A,a}	7.61 ± 0.21 ^{AB,ab}
CS/BEO	6.82 ± 0.33 ^{B,a}	7.05 ± 0.32 ^{AB,a}	7.09 ± 0.35 ^{AB,a}	7.28 ± 0.14 ^{A,a}	7.19 ± 0.20 ^{AB,b}
p value					
T			0.0095		
SP			<0.0001		
TxSP			0.0920		

$^{A–E;\ a,b}$ Different uppercase (row) or lowercase (column) letters indicate significant differences among means ($p < 0.05$). T, treatment; SP, storage period. * Egg grade: AA, excellent (≥72); A, high quality (71–60); B, average quality (59–31); and C, low quality (≤30) [25]; [1] Data are expressed as mean ± standard deviation (n = 8 quail eggs).

Coated eggs (CS/BEO) showed a more discreet reduction ($p < 0.05$) of HU than control eggs between the first and fourth weeks of storage (Table 6). When comparing these treatments, there was no difference ($p > 0.05$) between them (Table 6). In contrast, the average HU of the four weeks of storage of the CS/BEO (86.36 ± 4.84) was notably higher ($p < 0.05$) compared to the control (83.41 ± 7.00). This was yet another sign that BEO benefited the barrier property of the CS/BEO coating, conserving the albumen's complex protein network (ovomucin-lysozyme) and maintaining good albumen quality [26]. Less pronounced variations in HU reduction have also been reported for eggs coated with sweet potato starch plus thyme essential oil versus uncoated eggs [27].

In the third and fourth weeks of storage, the YI significantly differed ($p < 0.05$) between eggs from the control treatment and eggs from the CS/BEO treatment, with a higher value for CS/BEO (Table 6). This leads to the assumption that the structural configuration of the yolk formed mainly by the interaction of triacylglycerols, phospholipids, proteins, and carbohydrates [28], responsible for its viscous characteristic, was probably less disturbed in eggs coated with CS/BEO. This is due to the protective effect of CS/BEO against the impacts of temperature and storage time on yolk quality. Significantly higher YI values for eggs coated with rice protein mixed with tea tree, copaiba, or thyme essential oils compared with uncoated eggs were described by Pires et al. [29]

Significant changes ($p < 0.05$) in ApH values started from the third week of storage for the control treatment, while for eggs coated with CS/BEO the ApH was similar ($p > 0.05$) from the beginning to the end of storage (Table 6). In the fourth week of storage, the difference between these treatments was not significant ($p > 0.05$) (Table 6).

On the other hand, the mean ApH of the four weeks of storage was significantly lower ($p < 0.05$) for eggs with CS/BEO (9.53 ± 0.33) compared to eggs in the control treatment (9.80 ± 0.40). The most plausible justification for this finding suggests that the CS/BEO coating minimized the evaporation of water and carbon dioxide content through the pores or small deformations of the eggshell, causing the eggs to have albumen with better buffering capacity than coated eggs [30]. Reports are growing that polymer coatings containing essential oils positively influence albumen pH [22,31].

YpH values increased significantly ($p < 0.05$) for the control treatment in the second week of storage, reaching a value significantly higher ($p < 0.05$) than for CS/BEO coated eggs at the end of storage (Table 6). CS/BEO kept the YpH of the eggs in the last week similar ($p > 0.05$) to the initial YpH (Table 6). These findings corroborate the YI results. It is assumed that preserving the yolk protein structure minimized the release of basic nitrogenous compounds (for example, ammonia), causing no significant changes in yolk pH [28]. Another widespread hypothesis to explain this is associated with the water content that transits from the albumen to the yolk [32].

CS did not differ ($p > 0.05$) from the other treatments in any variable that measured internal egg quality (Table 6).

There was no significant difference between the sensory parameter scores of coated eggs and control treatment (Table 7). Therefore, the CS/BEO coating, besides preserving the eggs, does not leave noticeable traces (e.g., odor) that negatively influence consumer acceptability or preference. Protocols of application and evaluation of egg coatings with or without essential oil also showed no significant adverse effect on eggs to the point of being refused for consumption [6,33].

Table 7. Effect of corn starch coating plus basil essential oil (CS/BEO) on sensory parameters of quail eggs in the fourth week of storage at room temperature [1].

Treatments	Sensory Parameters					
	Color	Aroma	Odor	Texture	Taste	General Acceptability
Control	6.70 ± 2.36	8.20 ± 1.03	7.70 ± 1.57	7.80 ± 1.93	6.90 ± 3.03	7.20 ± 1.99
CS	7.70 ± 1.49	7.80 ± 1.75	7.70 ± 1.95	7.70 ± 1.06	7.90 ± 1.29	7.70 ± 0.95
CS/BEO	8.30 ± 1.34	7.90 ± 1.10	8.10 ± 0.99	7.80 ± 1.23	8.10 ± 1.10	8.10 ± 0.88
p value	0.1491	0.7858	0.8030	0.9844	0.3718	0.3522

[1] Data are expressed as mean ± standard deviation (n = 10 quail eggs). There is no significant difference among means ($p > 0.05$).

4. Conclusions

The CS/BEO coating formed on quail eggs is beneficial for maintaining their quality when stored under nonrefrigerated conditions for four weeks. This coating also reduced microorganisms in the shell and egg contents without interfering with consumer acceptability. BEO played a decisive additive role in maintaining egg quality.

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