Conservation of the internal quality of eggs using a biodegradable coating

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ABSTRACT This study aimed to evaluate the effect of a pectin biofilm on the preservation of refrigerated and unrefrigerated eggs during 5 wk of storage based on egg weight loss, albumen height, Haugh unit (**HU**), and the yolk index (**YI**). A total of 1,200 nonfertile eggs from GLK Bankiva laying hens (40 wk of age), which were freshly laid and came from a single collection, were obtained from a model poultry rearing system (Planaltina, Federal District, Brazil) that meets all animal welfare criteria. The experimental outline was entirely randomized, with 20 treatments in a factorial scheme of 2 × 2 × 5, with 2 biofilm treatments (with and without) × 2 storage temperatures (refrigeration: 5°C and ambient: 25°C) × 5 storage periods (7, 14, 21, 28, and 35 d), with 12 repetitions per treatment. Starting from the third storage week, increased weight loss (%) was observed in noncoated eggs (4.46 ± 1.06; 5.61 ± 1.37; 6.93 ± 1.66%) compared with biofilm-coated eggs (3.57 ± 1.26; 4.74 ± 1.8; 6.05 ± 2.21%), respectively. The HU variation in the pectin-coated eggs (86.84–78.02) was smaller than that in the noncoated eggs (83.01–64.36) between the beginning (7 d) and the end (35 d) of the experimental period. Eggs with and without biofilm stored in the refrigerator presented average HU values of 91.26 ± 6.27 and 88.35 ± 6.96, respectively. In contrast, when kept at room temperature, eggs with the coating presented higher HU values (71.27 ± 10.78) than eggs without the coating (59.11 ± 15.97). Coated eggs (0.37 ± 0.16) showed higher YI values than noncoated eggs (0.35 ± 0.16). A pectin-based biofilm effectively maintained egg quality during the 35 d of storage.

Key words: biofilm, egg quality, Haugh unit, pectin, shelf life

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INTRODUCTION

The nutritional value of the egg is based on its quality. Immediately after an egg is laid, it begins to deteriorate, and the internal and external quality of the egg begins to decrease. This process is inevitable and continuous and can be worsened by unmet storage requirements, such as temperature and storage period (Samli et al., 2005). The most effective way to prevent the loss of internal quality is through refrigeration (Feddern et al., 2017). However, owing to the high cost and lack of refrigeration requirements in some countries, eggs are kept at ambient temperature.

Lengthening the shelf life of eggs while maintaining the same quality as fresh eggs is a challenge that relies on several factors. The most important factor influencing the quality of eggs is temperature. At high temperatures, eggs quickly lose their quality, primarily because of the rapid physical–chemical changes that occur. However, egg coatings can be used to limit the loss of water and the transport of oxygen and carbon dioxide (Guilbert et al., 1997), thereby maintaining the shelf life of eggs.

Coatings are an emulsion applied directly onto a food surface, which leaves a thin film on the product after drying, and that plays an important role in the conservation of food products (Gennadios and Weller, 1990; Falguera et al., 2011; Camatari et al., 2017). Several egg coatings, such as chitosan, starch cassava and yam, whey protein concentrate, soy protein isolate, and vegetable oils, have been evaluated (Alleoni and Antunes, 2004; Ryu et al., 2011; Suresh et al., 2015; Almeida et al., 2016; Mota et al., 2017; Xu et al., 2017). Therefore, there is great enthusiasm for developing edible or biodegradable films

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for egg protection, primarily owing to concerns about the disposal of nonrenewable material.

During the industrial fruit juicing process, for example, a large amount of residues, such as skin, seeds, and moist pulp, are created. These residues are full of nutrients and other substances that can be reused in the food industry, such as pectin (Espinoza et al., 2018). Pectin is a water-soluble anionic polysaccharide that is available in the primary cell wall of many plant species and is extracted primarily from the skins of citrus fruits and from apple pulp (Thakur et al., 1997; Canteri-Schemin et al., 2005). Pectin has the ability to thicken and stabilize emulsions and participates in the formation of a thick film that assists in reducing food mass weight loss (Almeida and Montibeller, 2016).

Pectin is an important industrial processing by-product of several fruits, which presents being potential as a component of films. However, very few scientific studies have been devoted to investigate the use of pectin as a coating and its role in maintaining the internal quality of eggs intended for human consumption. In this context, this kind of coating should be evaluated as a way to preserve eggs, considering that new alternatives for egg storage are essential for maintaining the properties of fresh eggs. This study aimed to evaluate the effect of a pectin biofilm on the preservation of refrigerated and unrefrigerated eggs during 5 wk of storage based on egg weight loss, albumen height, Haugh unit (**HU**), and the yolk index (**YI**).

MATERIALS AND METHODS

A total of 1,200 nonfertile eggs from GLK Bankiva laying hens (40 wk of age), which were freshly laid and came from a single collection, were obtained from a model poultry rearing system (Planaltina, Federal District, Brazil) that meets all animal welfare criteria.

The pectin biofilm was prepared as per the method described by Zactiti and Kieckbusch (2006) with adaptations. For the preparation, 3.6 g glycerol (plasticizer) was dissolved in 400 mL distilled water using a magnetic mechanical agitator (Novatecnica, Piracicaba, São Paulo, Brazil) with a heater. Afterward, 6 g pectin (biopolymer) was added, and agitation was maintained until the pectin was completely dissolved. Next, the solution was heated to 70°C in an agitator and prelatticed with 30 mL calcium chloride by adding 5 mL every 3 min.

After cooling, the solution was sprayed with a hand sprayer. All coated eggs were naturally dried at ambient temperature (25°C) and were positioned on a half-inch wire mesh. Once coated, the eggs were divided into 2 experimental groups: refrigeration (5°C) and ambient temperature (25°C). The control group eggs did not receive any coating but were stocked at the same temperatures as the coated eggs.

The evaluated parameters were egg weight loss (%), albumen height (mm), HU, and YI.

All eggs were weighed with a 0.001-g precision scale (Gehaka, São Paulo, São Paulo, Brazil) to obtain their initial weight. Final weights were measured after each storage period (7, 14, 21, 28, and 35 d). With those data, the egg weight loss percentage was calculated by the difference between initial egg weight and final egg weight divided by the initial egg weight and multiplied by 100.

To determine the HU, the eggs were broken on a glass plane to measure albumen height using a digital micrometer (Mitutoyo, Suzano, São Paulo, Brazil). To obtain HU values, the logarithmic relationship between albumen height and egg weight was taken into account. With this information, a descriptive formula from the study by Pardi (1977) was used to calculate the HU: $HU = 100 \log (H + 7.57–1.7\ W^{0,37})$, where H represents the albumen height (mm) and W represents the egg weight (g).

The HU is a quality criterion for egg internal quality, and this parameter is expressed as a score between 0 and 100. Eggs are classified as AA, excellent when the HU measures between 100 and 72; as A, high quality between 71 and 60; as B, average quality between 59 and 30; and as C, low quality between 29 and 0, as per the USDA egg classification manual (USDA, 2000).

The YI is based on the relationship between the yolk height and the yolk diameter. After separating the yolk from the albumen, the height of the yolk was determined using a digital micrometer (Mitutoyo, Suzano, São Paulo, Brazil), and a digital caliper (Mitutoyo, Suzano, São Paulo, Brazil) was used to measure the diameter of the yolk. The YI was obtained by the formula described by Funk (1973): $YI = h/d$, where h is the yolk height (mm), and d is the yolk diameter (mm).

The experimental outline was entirely randomized, with 20 treatments in a factorial scheme of $2 \times 2 \times 5$, with 2 biofilm treatments (with and without) $\times$ 2 storage temperatures (refrigeration: 5°C and ambient: 25°C) $\times$ 5 storage periods (7, 14, 21, 28, and 35 d), with 12 repetitions per treatment. Each egg was considered a repetition (experimental unit). Data were subjected to ANOVA using the PROC GLM procedure in the auxiliary software for SAS University Studio (Inst. Inc., Cary, NC). The Tukey test at 5% significance was performed for the subsequent average values. The correlation between all measured variables (egg weight loss, albumen height, HU, YI) was determined using the PROC CORR procedure.

RESULTS AND DISCUSSION

The mean egg weight loss (%), albumen height (mm), HU, and YI values for each treatment factor (with and without biofilm; storage period and storage temperature) are shown in Table 1. An effect of the interaction ($P = 0.0142$; CV = 29.90%) between the use or absence of biofilm and the storage period of the eggs was observed on egg weight loss (%) (Figure 1).

At 7 and 14 storage day, the average loss between coated eggs (1.26 ± 0.53 and 2.54 ± 0.87%) and non-coated eggs (1.43 ± 0.32 and 2.87 ± 0.72%), respectively, was similar. Starting from the third storage

Table 1. Effect of treatment factors (with and without biofilm; storage period and storage temperature) on egg weight loss (%), albumen height (mm), HU, and YI.[1]

Treatment	Egg weight loss (%)	Albumen height (mm)	HU	YI
Without biofilm	4.26 ± 2.25[a]	5.91 ± 2.29[b]	73.73 ± 19.13[b]	0.35 ± 0.16[b]
With biofilm	3.63 ± 2.21[b]	6.71 ± 2.00[a]	81.27 ± 13.34[a]	0.37 ± 0.16[a]
Storage period				
7 d	1.34 ± 0.44[e]	7.31 ± 1.78[a]	84.92 ± 10.94[a]	0.38 ± 0.13[a]
14 d	2.71 ± 0.81[d]	6.52 ± 1.78[b]	79.84 ± 11.76[b]	0.37 ± 0.17[a,b]
21 d	4.01 ± 1.24[c]	6.41 ± 2.12[b]	78.36 ± 15.18[b]	0.37 ± 0.16[a,b]
28 d	5.17 ± 1.64[b]	5.76 ± 2.30[c]	73.17 ± 19.32[c]	0.35 ± 0.16[b,c]
35 d	6.49 ± 1.99[a]	5.56 ± 2.46[c]	71.19 ± 21.57[c]	0.32 ± 0.15[c]
Storage temperature				
Refrigerated	2.95 ± 1.56[b]	7.99 ± 1.22[a]	89.80 ± 6.76[a]	0.40 ± 0.18[a]
Ambient	4.94 ± 2.39[a]	4.63 ± 1.53[b]	65.19 ± 14.88[b]	0.32 ± 0.13[b]
P-value	<0.0001	<0.0001	<0.0001	<0.0001

Means with different superscript letters in columns differ significantly ($P < 0.05$).
Abbreviations: HU, Haugh unit; YI, Yolk index.
[1]Results are expressed as means ± SD.

week, increased weight loss (%) was observed in noncoated eggs (4.46 ± 1.06; 5.61 ± 1.37; 6.93 ± 1.66%) compared with biofilm-coated eggs (3.57 ± 1.26; 4.74 ± 1.8; 6.05 ± 2.21%), respectively. Corroborating these results, Caner and Yüceer et al. (2015) analyzed the efficacy of several coatings on eggs (whey protein concentrate, whey protein isolate, zein, and shellac) for 6 wk at 24°C and observed a greater loss of egg weight for the control group (6.71 ± 0.73%) when compared with eggs coated with whey protein concentrate (4.59 ± 0.18%), whey protein isolate (4.60 ± 0.41%), zein (2.13 ± 0.39%), and shellac (1.44 ± 0.10%).

Our results suggest that the pectin-based coating was determinant in egg weight loss as a result of the barrier created between the internal content and the external ambient. This probably reduced the permeability of gases, resulting in decreased weight loss from the coated eggs.

An effect of the interaction ($P = 0.0010$; CV = 49.18%) between the storage temperature and the biofilm application on egg weight loss was observed (Figure 2). At ambient temperature, the coating effectively reduced egg weight loss (4.77 ± 2.34%) compared with eggs without the coating (5.11 ± 2.45%). Under refrigeration, pectin-coated eggs exhibited reduced weight loss (2.49 ± 1.32%) compared with eggs without coating (3.41 ± 1.65%).

When evaluating the quality of eggs coated with odorless petroleum jelly and paraffin wax stored under refrigeration and at room temperature (28°C–31°C), Shittu and Ogunjinmi (2011) noticed similar results to those reported in this study. The authors examined eggs coated with odorless petroleum jelly and paraffin wax in a combined manner, and odorless petroleum jelly exhibited the least weight loss under refrigeration (0.34%; 0.74%) and at room temperature (1.05 and 3.46%) compared with uncoated eggs (3.56 and 5.46%) in the same conditions, respectively, at the end of the sixth week of storage. Therefore, the coating decelerated egg weight loss even more.

An effect of the interaction ($P < 0.0001$; CV = 17.74%) between the storage temperature and the number of storage day on egg weight loss was observed (Figure 3). The weight loss maintained the same increasing trend during the storage period in refrigerated eggs (5°C) as in eggs at ambient temperature (25°C). However, eggs stored at ambient temperature showed higher average weight loss (8.10 ± 1.11%) during the total storage period (35 d), whereas refrigerated eggs lost an average of 4.88 ± 1.20% of their weight during the same period.

Santos et al. (2009) analyzed the factors of conservation temperature (27.84°C and 4.65°C) and storage period (7, 14, and 21 d) and observed that commercial eggs stored for 21 d exhibited greater weight loss than eggs stored for shorter periods (7 and 14 d). Regardless of the storage period, eggs at room temperature (3.42%) lost more weight than refrigerated eggs (1.99%). The authors stated that egg weight loss occurs because of the reduction in water in the egg white because its proportion decreases linearly as a function of the storage period, and this loss is significantly more pronounced in eggs kept at room temperature.

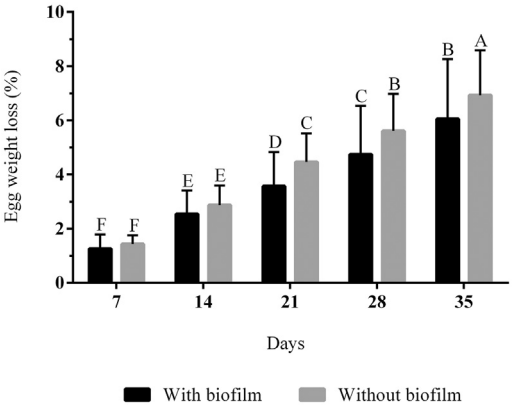

Figure 1. Interaction ($P = 0.0142$; CV = 29.90%) between the coating (with and without biofilm) and storage period (d) on egg weight loss (%). [A–F]Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean egg weight loss ± SD.

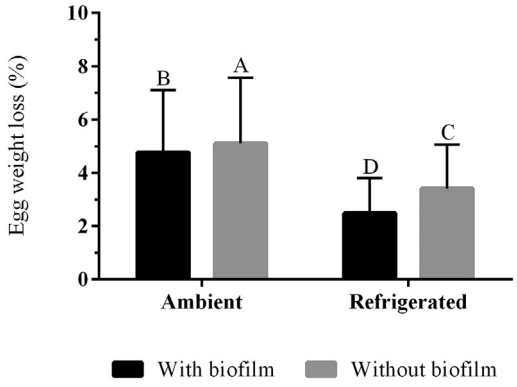

Figure 2. Interaction ($P = 0.0010$; CV = 49.18%) between the storage temperature (°C; ambient and refrigerated) and coating (with and without biofilm) on egg weight loss (%). $^{A-D}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean egg weight loss ± SD.

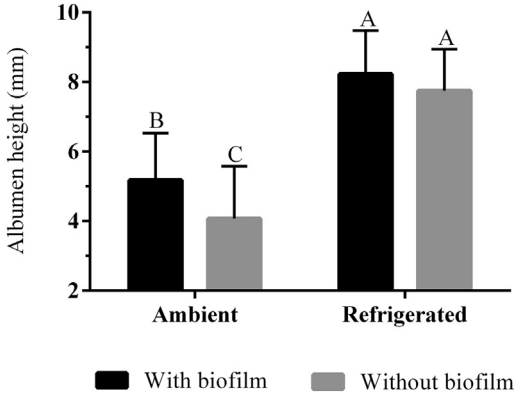

Figure 4. Interaction ($P = 0.0323$; CV = 20.85%) between coating (with and without biofilm) and storage temperature (°C; ambient and refrigerated) on albumen height (mm) of the eggs. $^{A-C}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean albumen height ± SD.

A significant interaction effect ($P = 0.0323$; CV = 20.85%) between biofilm use and egg storage temperature on albumen height was observed (Figure 4). Albumen height did not significantly differ between coated (8.23 ± 1.21 mm) and uncoated (7.75 ± 1.19 mm) eggs when the eggs were chilled at 5°C. For eggs kept at 25°C, the average albumen height of coated eggs was 5.18 ± 1.35 mm, which was greater than in the uncoated eggs (4.07 ± 1.51 mm).

The results found in this study corroborate the descriptions of Pleti et al. (2009). According to these authors, there is a decrease in egg albumen viscosity with increased storage time, and this decrease may happen faster when eggs are stored at ambient temperature. Although refrigeration is the primary method for egg conservation, it is worth noting that the biofilm effectively maintained greater albumen consistency in the coated eggs at both storage temperatures.

An interaction effect ($P = 0.0007$; CV = 18.97%) between storage period and storage temperature on albumen height was observed (Figure 5). From the seventh to the 35th d, refrigerated eggs showed equal average values for albumen height (7.99 ± 0.39 mm). However, the albumen height decreased as the storage time increased, and this decrease being significant at room temperature. At 7 d, an average albumen height of 6.07 ± 1.29 mm was measured; this value decreased at 14 (5.15 ± 0.88), 21 (4.63 ± 1.25), and 28 (3.72 ± 1.15) d, finally reaching a height of 3.56 ± 1.52 mm at 35 d.

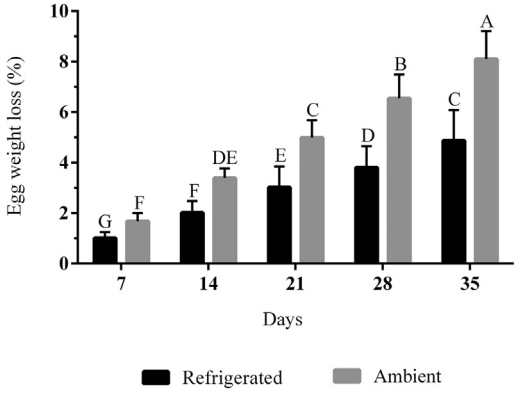

Figure 3. Interaction ($P < 0.0001$; CV = 17.74%) between storage temperature (°C; ambient and refrigerated) and storage period (d) on egg weight loss (%). $^{A-G}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean egg weight loss ± SD.

The condition of albumen is affected by both the storage period and temperature, and its integrity is directly related to the measurement of internal egg quality. In the present study, it was possible to verify the positive effect of refrigeration on the maintenance of albumen height. Lana et al. (2017) also found a significant reduction in egg albumen height from the sixth to the 30th d of storage in eggs kept at 26.5°C ± 0.7°C (3.76 mm) compared with eggs cooled to 7.3°C ± 0.5°C (6.75 mm). Both results are caused by liquefaction of the thick albumen structure during the storage period; the liquefaction process is accelerated by high ambient temperatures.

For the HU, there was an interaction effect ($P = 0.0010$; CV = 19.55%) of storage d and biofilm application (Figure 6). There was a decrease in the HU value of eggs during storage, regardless of the use or absence of the biofilm. The decrease in HU values is associated with a reduction in internal egg quality. In this study, HU variation in the pectin-coated eggs (86.84–78.02) was smaller than in the noncoated eggs (83.01–64.36) between the beginning (7 d) and the end (35 d) of the experimental period.

Ryu et al. (2011) compared different egg coatings (mineral oil and 6 sources of vegetable oil: canola, corn, grape seed, olive, soybean, sunflower) and reported that significant changes occurred in the HU in both uncoated and coated egg samples during 5 wk of storage. As per their results, the HU decreased with increasing storage time; however, this decrease progressed at a much slower rate for oil-coated (84.65 ± 3.65–63.33 ± 4.67) eggs than for uncoated (84.65 ± 3.65–43.61 ± 4.15) eggs.

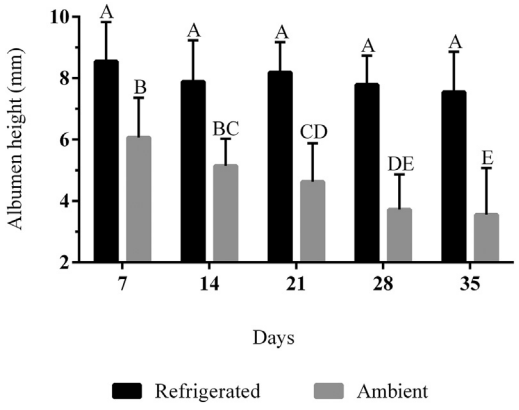

Figure 5. Interaction ($P = 0.0007$; CV = 18.97%) between storage period (d) and storage temperature on albumen height (mm) of the eggs. $^{A-E}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean albumen height ± SD.

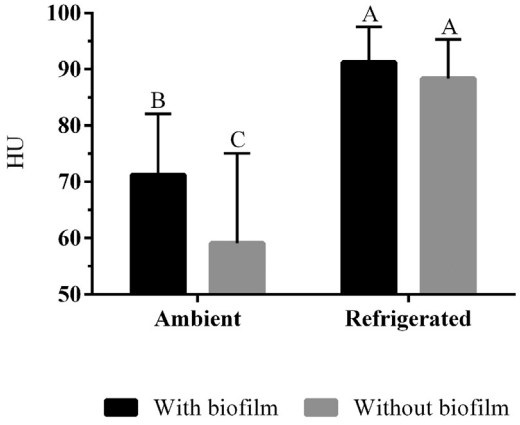

Figure 7. Interaction ($P < 0.0001$; CV = 12.90%) between storage temperature (°C; ambient and refrigerated) and coating (with and without biofilm) on Haugh unit (HU) of the eggs. $^{A-C}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean HU ± SD.

The HU showed an interaction effect ($P < 0.0001$; CV = 12.90%) of the storage temperature and the biofilm application (Figure 7). Eggs with and without biofilm stored in the refrigerator presented average HU values of 91.26 ± 6.27 and 88.35 ± 6.96, respectively, which were statistically equal and indicated "AA" rated eggs (USDA, 2000). In contrast, when kept at room temperature, eggs with the coating presented higher HU values (71.27 ± 10.78) than eggs without the coating (59.11 ± 15.97), and these eggs were classified as "A" and "B," respectively.

Torrico et al. (2014) found similar results. According to these authors, the HU of all coated eggs (mineral oil: chitosan at 25:75) decreased slowly over the storage period; however, the eggs in a refrigerated ambient maintained higher HU values (87.8 ± 5.0–61.4 ± 5.6), consistently maintaining an "A" grade for a long period of storage (20 wk) at 4°C ± 2°C compared with 4-wk storage at 25 ± 2°C (87.8 ± 5.0–60.1 ± 3.9).

The HU values are associated with good egg quality (Stadelman, 1995a). In our study, the covering effectively maintained the quality of eggs because they presented different HU results both under refrigeration (5°C) and at room temperature (25°C), and the covering was more relevant for eggs kept at 25°C.

An interaction effect ($P < 0.0001$; CV = 11.92%) between storage d and storage temperature was observed on the HU (Figure 8). During the 35 d of storage, refrigerated eggs presented statistically similar averages (89.80 ± 1.72) and were classified as excellent (AA). Eggs at ambient temperature decreased in HU values starting in the first week (77.52 ± 9.25); however, they were also classified as excellent (AA). During the second and third week (70.76 ± 7.45 and 66.15 ± 11.59, respectively), eggs were classified as high quality (A), and in the fourth and fifth week (56.97 ± 13.06 and 54.56 ± 17.87, respectively), they were classified as medium quality (B).

The HU was positively correlated (r = 0.9792; $P < 0.0001$) with albumen height, emphasizing the influence of this variable for measuring the internal quality of eggs. Thus, a decrease in HU values is related to a decrease in egg quality. This reduction is primarily

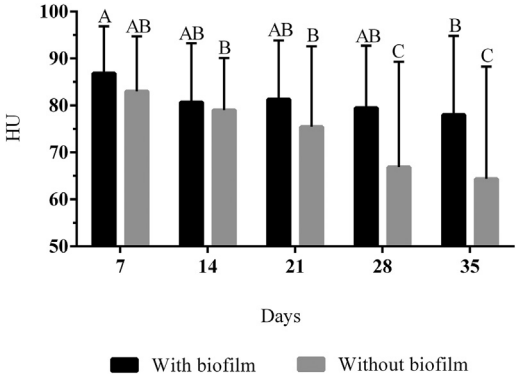

Figure 6. Interaction ($P = 0.0010$; CV = 19.55%) between storage period (d) and coating (with and without biofilm) on Haugh unit (HU) of eggs. $^{A-C}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean HU ± SD.

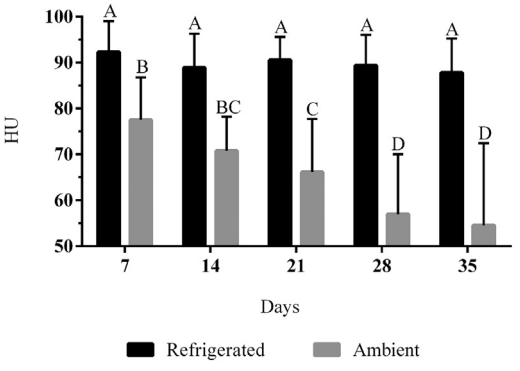

Figure 8. Interaction ($P < 0.0001$; CV = 11.92%) between storage period (d) and storage temperature (°C; ambient and refrigerated) on Haugh unit (HU) of the eggs. $^{A-D}$Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean HU ± SD. Abbreviation: CV, coefficient of variation.

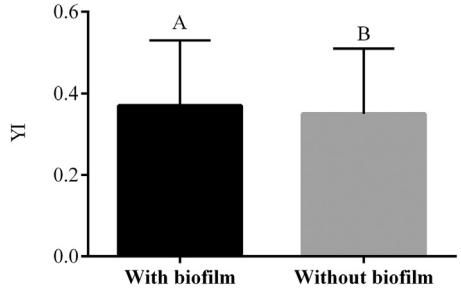

Figure 9. Yolk index (YI) ($P < 0.0001$; CV = 44.05%) of coated and noncoated eggs. [A,B]Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean YI ± SD. Abbreviation: CV, coefficient of variation.

associated with the loss of water and carbon dioxide through during the period of ambient temperature elevation (Silva et al., 2015; Lana et al., 2017). However, refrigeration systems reduce this deterioration in eggs and consequently increase their quality (Stadelman 1995b; Giampietro-Ganeco et al., 2012), reinforcing the importance of temperature in maintaining the internal quality of eggs.

For the YI, a significant difference ($P < 0.0001$; CV = 44.05%) was observed when the biofilm coating was applied (Figure 9). Coated eggs (0.37 ± 0.16) showed higher YI values than noncoated eggs (0.35 ± 0.16). Thus, the coating was effective in maintaining egg quality, although both types of eggs had YI values that met the standard for fresh eggs (0.30–0.45) (Romanoff and Romanoff, 1963; Santo et al., 2017).

Almeida et al. (2016) examined the physicochemical quality of commercial eggs subjected to cleaning and submersion in whey protein concentrate for 7 storage periods (1, 7, 14, 21, 28, 35, and 42 d), reporting that eggs that were uncleaned and coated with milk protein had a higher YI from 7 to 42 d of storage (0.44–0.34) compared with uncleaned and uncoated (0.43–0.32), cleaned and coated (0.43–0.31), and cleaned and uncoated (0.42–0.30) eggs. This result illustrates the importance of the cuticle and coating for maintaining egg quality.

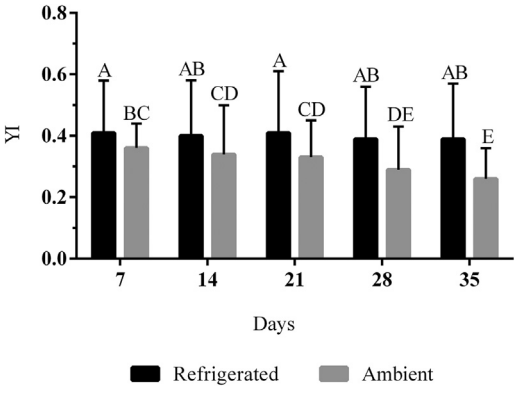

Figure 10. Interaction ($P < 0.0001$; CV = 41.85%) between storage temperature (°C; ambient and refrigerated) and storage period (d) on yolk index (YI) of the eggs. [A–E]Means with different capital letters indicate statistically significant differences ($P < 0.05$). Results are expressed as mean YI ± SD.

There was an interaction effect ($P < 0.0001$; CV = 41.85%) of storage temperature and d of storage on the YI (Figure 10). Eggs kept under refrigeration (5°C) presented YI values between 0.41 (7 d) and 0.39 (35 d), whereas eggs kept at ambient temperature (25°C) obtained averages between 0.36 (7 d) and 0.26 (35 d).

In this sense, Fernandes et al. (2015) analyzed the quality of white and red eggs during winter and summer and found that YI in summer was 0.23 and in winter was 0.41 for both white and red eggs. As per their results, high temperatures may have negatively affected egg quality. During prolonged storage, albumen liquefies, and this process occurs faster at ambient temperature. Thus, the yolk absorbs water from the liquefied albumen and becomes decentralized and less dense, which reduces its the height and increases its the diameter, negatively affecting YI (Obanu and Mpieri, 1984; Stadelman, 1995a; Mineki and Kobayashi, 1998).

CONCLUSIONS

A pectin-based biofilm effectively maintained egg quality during 35 d of storage. Based on weight loss and HU values, the biofilm coating increased the shelf life of eggs at ambient temperature compared with that of noncoated eggs. Future studies are needed to investigate whether the use of pectin also contributes to the microbiological quality of eggshells.

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DISCLOSURES

The authors declare no conflicts of interest.

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