USE OF COATING BASED ON CASSAVA STARCH ON THE QUALITY OF FREE-RANGE EGGS STORED AT ROOM TEMPERATURE

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This study aimed to evaluate the quality of free-range eggs storage at room temperature and coated with different levels of cassava starch. A total of 255 fresh eggs coated with a cassava starch solution at the levels of 0, 1, 3 or 5% were used. The eggs remained stored for 28 days at room temperature. The experimental design was completely randomized, distributed in a 4x4+1 factorial arrangement with 4 levels of cassava starch, in 4 periods (7, 14, 21 and 28 days) and the eggs collected on the first day. The eggs uncoated and with 1% starch presented the highest weight loss, respectively, 4.02% and 3.97% (P <0.001), eggs with 3% and 5% starch presented a reduction of weight loss, 3.17% and 2.22% (P <0,001), respectively, and higher Haugh Units (P <0.001). The 5% starch coating was efficient during storage, maintaining the same percentage of yolk (P <0.05) and albumen (P <0.05) for 14 days. Levels of 3 and 5% cassava starch improved the internal quality of the eggs during storage and can be an effective alternative to extend the shelf life of free-range eggs.

INDEX TERMS: ALBUMEN, EDIBLE COATINGS; EGGSHELL, EGG QUALITY,

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INTRODUCTION

Eggs are an excellent natural source of energy and high-quality protein, in addition to other nutrients such as vitamins, antioxidants, carotenoids, and phospholipids (Lesnierowski & Stangierski, 2018). The demand for food from extensive production systems, such as free-range egg production, increased because of consumers' concerns about the use of the cage environment (El-Deek & El-Sabrout, 2019). Several studies have demonstrated the effects of alternative production systems on egg quality and chemical composition. Some quality characteristics of the egg are higher in eggs produced in cages when compared to alternative systems (Englmaierová et al., 2014). Decrease in shell thickness was observed in eggs produced in the outdoors when compared to eggs produced in cages (Tumova & Ebeid 2005). The eggshell is considered an efficient natural packaging. However, eggs are a perishable product and lose quality during the storage period. The eggshell is essential to maintain the integrity of the internal egg components. Reduced eggshell quality favors carbon dioxide loss and moisture through the shell pores.

To mitigate these problems, storage technologies have been developed to extend the shelf life of eggs. Such is the case with the edible coatings that demonstrates favorable results using simple polysaccharides materials for egg preservation, (Jo et al., 2011; Eddin et al., 2019). Starch is a very abundant natural polysaccharide and is normally a mixture of amylose and amylopectin. Mota et al., (2017) demonstrated that cassava and yam starch coatings can be a viable option for maintaining the internal quality of conventional eggs. Laying hens reared in free-range system have access to pasture, unlike the conventional system where they are kept in cages. Popova et al (2020) comparing the two systems, observed that free-range eggs had a larger diameter and yolk weight, as well as larger diameters and albumen index. However, they had a thinner shell and lower Haugh units. In addition, alternative eggs, such as free-range, have a higher cost and lower sales volume when compared to conventional eggs and tend to remain for a longer period on market shelves, so greater loss of quality could be expected in products with a narrower market. The aim of the present study was to evaluate the internal quality of free-range eggs during storage at room temperature (± 20°C) coated with different levels of cassava starch.

MATERIAL AND METHODS

This study used a total of 255 fresh eggs from Hy-Line Brown laying hens from the Poultry Sector of the Universidade Federal de Santa Catarina, in which the birds were reared in a free-range system. The selected eggs had a mean weight of 64.1 ± 1.19g and were individually identified, weighed on the day of collection and stored at room temperature.

The solutions were prepared at concentrations of 1, 3 and 5% cassava starch in water and were heated to 70°C for starch gelatinization and cooled to 20°C according to the methodology of Hojo et al. (2007). Eggs were immersed in the solutions for one minute and then suspended to dry naturally. The uncoated eggs were used as the control treatment. A thermohygrometer was installed in the room where the eggs were stored for recording temperature and humidity.

On days 0, 7, 14, 21 and 28, 15 eggs per treatment, were evaluated following egg quality parameters: weight loss (%), albumen height, Haugh unit (HU), yolk index, yolk weight, albumen weight, albumen, and yolk pH. Fifteen eggs were immediately submitted to quality analysis to represent the characteristics of fresh eggs (zero days of storage).

To determine the weight loss (%), the stored eggs were weighed individually on a semi-analytical balance with an accuracy of 0.01 g (BL3200H, Shimadzu, Tokyo, Japan) on day zero of storage and in their respective weeks. Thus, the difference between the initial and final weight provided the values of weight loss in grams, as shown in the equation below:

Eq 1: $\text{Weight loss} = ((FW\text{-}IW)/IW) \times 100$:

Where: FW: final weight; and IW: initial weight.

Albumen and yolk were weighed separately on semi-analytical balance with an accuracy of 0.01 g (BL3200H, Shimadzu, Tokyo, Japan) The percentage of albumen and yolk was calculated as a function of egg weight.

The albumen height was measured with a digital caliper (Toolsworld, MTX 316119) with a precision of 0.01m, at a distance of 10 mm from the yolk. The Haugh unit was obtained through the equation:

Eq 2: Haugh unit = $100 * \log (H - 1.7W^{0.37} + 7.6)$,

Where: H: albumen height (mm); and W: weight (g) of egg.

The yolk width and height (mm) were measured with a digital caliper (Toolsworld, MTX 316119, China). The yolk index was calculated by dividing the yolk height by the yolk width (mm).

After separating the albumen from the yolk, both were weighed individually and immediately afterwards were homogenized for 20 seconds and the pH was determined using a digital pH meter (Kasvi, K39-1014B, Brazil).

The experimental design was completely randomized, distributed in a 4 x 4 +1 factorial arrangement, with 4 levels of starch (0, 1, 3 and 5%), stored in 4 periods (7, 14, 21 and 28 days) and the eggs collected on the first day, with 15 replicates, in which the egg is the experimental unit. Statistical analyses were performed using SAS statistical software (9.4, SAS Inst. Inc., Cary, NC, USA). The normality of the data was checked using the Shapiro-Wilk test, with PROC UNIVARIATE. Data were tested by analysis of variance using PROC GLM and means were compared by Tukey's test ($p < 0.05$). Models included the effects of starch levels, the storage period, and the interaction between them.

RESULTS AND DISCUSSION

Egg weight loss is an important feature to assess egg quality during the storage period (Pires et al., 2021). Water loss depends on many factors such as temperature, airflow and relative humidity during the storage period. The evaluation of weight loss becomes a great tool to monitor the quality of eggs, because soon after the egg laying starts the process of reducing its internal quality (Barbosa et al*.,* 2008).

Egg weight loss increased progressively with increasing storage periods (Table 1). In the four periods evaluated, uncoated eggs and those coated with 1% starch showed a greater weight loss than those with 3% and 5% starch coating. In this study, coating eggs with 3 or 5% starch kept weight loss within the range of 3.17% and 2.22%, respectively, at 4 weeks of storage, which was not observed in uncoated eggs and eggs coated with 1% starch (4.02 and 3.97%, respectively) in this same period. Weight loss in conventional eggs during storage has been reported in previous studies. Pires et al., (2021) found a weight loss of 5.41% in uncoated eggs stored at 20ºC for six weeks. Egg weight loss is caused due to the transfer of moisture from the albumen to the external environment through the eggshell (Scott & Silversides 2000).

The coatings form a physical barrier, so there is less moisture transfer from the albumen to the external environment, less liquefaction of the albumen and consequently provides less weight loss. Several studies have shown a decrease in weight loss with the use of coatings during storage (Pujols et al., 2014). Eddin and Tahergorabi (2019) observed that eggs that were coated with sweet potato starch had significantly less weight loss compared to uncoated eggs. In starch coatings, gas transfer occurs through the non-crystalline regions of the material (amorphous areas), and the advancement of the recrystallization process reduces the amorphous regions, providing less space for gas transfer (Liu, 2005). The water vapor permeability of cassava starch coating is between 3.27×10^{-12} g m^{-1} Pa^{-1} s^{-1} and 15.70×10^{-12} g m^{-1} Pa^{-1} s^{-1} (Pérez-Vergara et al., 2020). The permeability should be as low as possible because the main function of food packaging is often to avoid or decrease moisture transfer between the food and the atmosphere (Mali et al., 2006).

There was no interaction effect between storage period and coating levels on HU. Eggs coated with 3% and 5% starch obtained a higher HU when compared to control or eggs with 1% starch (Figure 1). There was a difference in the storage period of eggs, regardless of coating in relation to the height of albumen, which serves as a parameter for measuring UC, which agrees with previous studies Ezazi et al., (2021). The highest height and HU occurred on day zero of storage and decreased significantly on the following measurement days: 7, 14, 21 and 28. Only days 21 and 28 did not differ from each other.

The data for yolk and albumen percentage are listed in Table 2. There was interaction ($P < 0.05$) of storage period and coating on percentages of yolk, albumen and yolk index. When breaking down the interactions between time and coating, it was observed that there was a reduction in albumin percentage for all treatments from day 14 onwards, except for the eggs that received the coating at the 5% cassava starch level. The yolk percentage for the control treatment increased at day 14, for those that received the coating, it increased only at day 21. For the yolk index, the treatments with 3 and 5% showed similar behaviour, evidencing the highest indices, regardless of the period evaluated.

Among the factors that may influence the quality of albumen are the time and temperature of egg storage. With increasing time and temperature, there will be a decrease in albumen height and, consequently, in HU. This occurs due to enzymatic reactions in the albumen, the enzymes hydrolyze the amino acid chains and, destroying the protein structure, release the water bound to the protein molecules, causing fluidization and loss of viscosity of the denser part of the albumen (Oliveira & Oliveira 2013). The higher the albumen height, the better the quality of the egg. Carvalho et al. (2013) reported a significant linear decrease in UC values in relation to egg storage time, indicating a reduction in internal egg quality loss. Pires et al. (2019a) reported that coated eggs maintained UC quality longer than uncoated eggs. This demonstrated that the use of coatings is a suitable tool to preserve the internal quality of eggs for longer, extending the shelf life of the product.

Liquefaction of the albumen causes a migration of water to the yolk, thus increasing its diameter, with a consequent reduction in its height, reducing the yolk index (Pissinati et al., 2014). The standard range for the yolk index of fresh eggs varies from 0.30 to 0.50. It is important to note that yolk index decreases significantly with increasing storage period (Pires et al., 2021). However, this study demonstrated that the use of coating was able to preserve the yolk quality longer time than uncoated eggs, which agrees with previous studies (Pires et al., 2020; Pires et al., 2021).

Table 3 presents the pH data of albumen and yolk. There was no variation in yolk pH, however, albumen pH was lower for eggs from the 3 and 5% starch treatments when compared to the zero and 1% coating treatments. At 0, 7 and 14 days there were significant differences in yolk and albumen pH, however, at 21 and 28 days there were no differences. After 4 weeks of storage, the pH of uncoated eggs increased from 8.07 to 9.18. After 4 weeks of storage, the yolk pH of uncoated eggs increased from 6.0 to 6.26.

The pH is a quality measure that varies according to the time and temperature of egg are stored and is considered as an indicator of freshness of eggs. In fresh eggs, the pH of albumen varies around 7.7, reaching 9.0 - 9.5 after storage. Pires et al. (2021), found similar pH values in uncoated eggs, with increase in albumen pH from 8.03 to 9.51 after six weeks of storage.

Variations in egg yolk pH can be expected because water migrates from the albumen to yolk during storage. The pH of the yolk of a fresh egg is approximately 6, but according to storage time it can rise up to 6.9. Previous research has documented a maximum increase in yolk pH from 6.24 to 7.0 (Pires et al. 2019b).

CONCLUSIONS

Cassava starch coatings at 3 and 5% levels proved to be efficient in extending the shelf –life of eggs while maintaining the internal quality at room temperature. The effects of using starch coatings on albumen and yolk quality are favorable, indicating that its use may be a viable alternative for maintaining the internal quality of eggs.

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TABLE 1 - EFFECT OF CASSAVA STARCH COATING ON THE WEIGHT LOSS PERCENTAGE OF EGGS DURING THE 28-DAY PERIOD. [1]

Coating	Storage days			
	7	**14**	**21**	**28**
0% starch	1.03 ± 018 Aa	2.12 ± 020 Ba	3.10 ± 0.14 Ca	4.02 ± 0.31 Da
1% starch	0.92 ± 0.10 Aa	2.50 ± 0.19 Ba	3.00 ± 0.20 Ca	3.97 ± 0.24 Da
3% starch	0.82 ± 0.10 Ab	1.43 ± 0.15 Bb	2.30 ± 0.22Cb	3.17 ± 0.23Db
5% starch	0.55 ± 0.28 Ac	1.10 ± 0.16 Bc	1.65 ± 0.31Cc	2.22 ± 0.18 Db

[1]Data are expressed as means ± standard deviations. Information was collected on 15 eggs per treatment. Statistical models included the effects of treatments, storage periods and interaction (treatments vs storage periods).
a-c Different lower case letters in the same column indicate means ± standard deviation that differ from each other by Tukey's test (<0.001).
A-D Different uppercase letters in the same row indicate means that differ from each other by Tukey's test (<0.001).

TABLE 2 – INTERACTION BETWEEN COATING AND STORAGE TIME FOR % ALBUMEN, % YOLK AND YOLK INDEX.[1]

Coating	Storage days			
	7	14	21	28 days
	% Albumen			
0% starch	63.64 ± 0.56 Aa	62.71 ± 0.56 Ba	61.82 ± 0.57 Ca	60.87 ± 0.65 Da
1% starch	64.86 ± 0.58 Aa	62.88 ± 0.57 Ba	61.95 ± 0.58 Ca	60.92 ± 0.65 Da
3% starch	63.83 ± 0.63 Aa	62.70 ± 0.56 Ba	62.30 ± 0.57 Ba	61.63 ± 0.56 Cb
5% starch	64.37 ± 0.65 Aa	64.37 ± 0.63Ab	64.00 ± 0.60 Ab	63.14 ± 0.57 Bb
	% Yolk			
0% starch	26.00 ± 0.58 Aa	27.36 ± 0.60 Ba	28.58 ± 0.58 Ca	29.52 ± 0.67 Da
1% starch	25.40 ± 0.60 Aa	27.49 ± 0.59 Aa	29.04 ± 0.58 Ba	29.11 ± 0.68 Ba
3% starch	26.22 ± 0.65 Aa	26.92 ± 0.57 Aa	27.79 ± 0.62 Bb	28.66 ± 0.60 Ca
5% starch	25.73 ± 0.57 Aa	25.28 ± 0.60 Ab	26.49 ± 0.67 Bb	27.15 ± 0.63 Bb
	Yolk index			
0% starch	0.43 ± 0.01 Aa	0.35 ± 0.01 Ba	0.33 ± 0.01 Ba	0.31 ± 0.01 Ca
1% starch	0.47 ± 0.01 Ab	0.39 ± 0.01 Bb	0.32 ± 0.01 Ca	0.32 ± 0.01 Ca
3% starch	0.47 ± 0.01 Ab	0.42 ± 0.01 Bc	0.36 ± 0.01 Cb	0.36 ± 0.01 Cb
5% starch	0.47 ± 0.01 Ab	0.42 ± 0.01 Bc	0.35 ± 0.01 Cb	0.36 ± 0.01 Cb

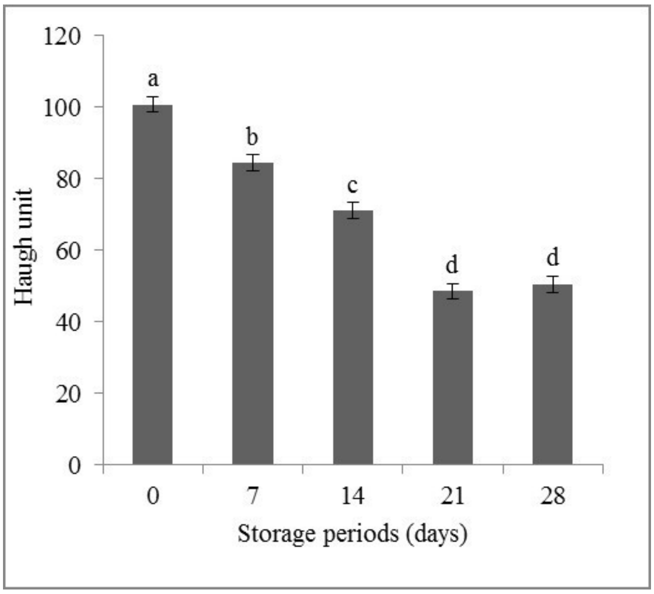
[1]Data are expressed as means ± standard deviations. Information was collected in 15 eggs per treatment. Statistical models included the effects of treatments, storage periods and interaction (treatments vs storage periods). a-c Different lowercase letters in the same column indicate means ± standard deviation that differ from each other by Tukey's test (<0.001). A-D Different uppercase letters in the same row indicate means that differ from each other by Tukey's test (<0.001).

TABLE 3 – VALUES OF YOLK AND ALBUMEN PH OF EGGS STORED FOR UP TO 28 DAYS, COATED WITH DIFFERENT LEVELS OF CASSAVA STARCH.[1]

Treatment	Yolk pH	Albumen pH
	Coating	
0% starch	6.25 ± 0.02	9.32 ± 0.03 a
1% starch	6.22 ± 0.02	9.28 ± 0.03 a
3% starch	6.26 ± 0.02	8.92 ± 0.03 b
5% starch	6.20 ± 0.02	8.89 ± 0.03 b
	Storage time	
0 days	6.00 ± 0.02 a	8.07 ± 0.03 a
7 days	6.13 ± 0.02 ab	8.92 ± 0.03 ab
14 days	6.21 ± 0.02 bc	9.05 ± 0.03 b
21 days	6.33 ± 0.02 c	9.26 ± 0.03 c
28 days	6.26 ± 0.02 c	9.18 ± 0.03 c
	Probabilities	
Storage time	0.0345	<0.0001
Coating	0.1491	<0.0001
Time * coating	0.2030	0.9870

[1]Data are expressed as means ± standard deviations. Information was collected in 15 eggs per treatment. Statistical models included the effects of treatments, storage periods and interaction (treatments by storage periods). a-c Different lowercase letters in the same column indicate means ± standard deviation that differ from each other by Tukey's test (<0.001). A-D Different uppercase letters in the same row indicate means that differ from each other by Tukey's test (<0.001).

A B



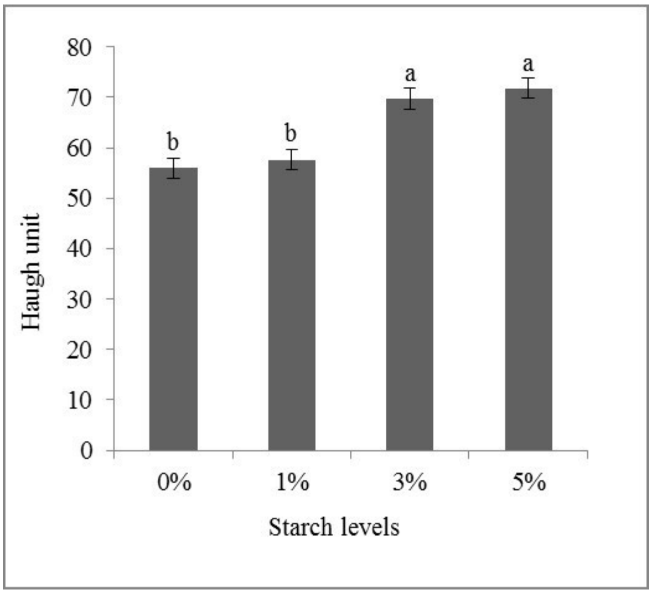


Figure 1 - Haugh Unit of eggs coated with different levels of cassava starch (A) and at different storage periods (B) Data are expressed as mean ± standard deviations. Information was collected on 15 eggs per treatment. Statistical models included the effects of treatments and storage periods.
a-d Different lower case letters indicate significant differences using Tukey's test (<0.001).