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EVALUATION OF THE QUALITY AND MECHANICAL RESISTANCE OF EGGS WITH THE APPLICATION OF BIODEGRADABLE COATINGS

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ABSTRACT

The chicken egg is one of the most complete and balanced foods for human nutrition, representing an important source of animal protein of the highest quality. The application of *coatings* can extend the shelf life of these foods, minimizing the migration of moisture, gases (CO_2 and O_2), solutes and volatile aromatic compounds, and can even function as a vehicle for food additives. The objective of the present work was to test theeffect of whey protein concentrate (WPC) based coatings with and without the addition of a lipid source (palm oil) on the quality and mechanical resistance of chicken eggs. The result of this study showed that the coating that offered the least loss of egg quality during storage was the WPC+oil coating. The presence of a lipid combined with a protein constituted a barrier to moisture and CO_2; consequently, this coating presented lower values for weight loss and pH, as well as higher values for Haugh unit and shell strength, characterizing better quality eggs.

Palavras-chave:
Recobrimento de alimentos
Vida de prateleira
Soro de leite
Ovo
Óleo de palma

AVALIAÇÃO DA QUALIDADE E RESISTÊNCIA MECÂNICA DE OVOS COM APLICAÇÃO DE REVESTIMENTOS BIODEGRADÁVEIS

RESUMO

O ovo de galinha é um dos alimentos mais completos e equilibrados para a alimentação humana, representando uma fonte importante de proteína animal da mais alta qualidade. A aplicação de coberturas (*Coatings*) pode prolongar a vida de prateleira desses alimentos, atuando na minimização da migração de umidade, de gases (CO_2 e O_2), de solutos e de compostos aromáticos voláteis, podendo funcionar até mesmo como veículo de aditivos alimentares. O objetivo do presente trabalho foi testar o efeito de coberturas a base de concentrado proteico de soro de leite (CPSL) com e sem a adição de uma fonte lipídica (óleo de palma) sobre a qualidade e a resistência mecânica de ovos de galinha. O resultado deste estudo mostrou que a cobertura que ofereceu a menor perda de qualidade dos ovos durante o armazenamento foi a cobertura de CPSL+óleo. A presença de um lipídio aliado a uma proteína constituiu uma barreira à umidade e ao CO_2 fazendo com que esta cobertura apresentasse menores valores para perda de peso, pH, maiores valores para a unidade Haugh e resistência da casca, caracterizando ovos de melhor qualidade.

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INTRODUCTION

Egg is a multifunctional food used by man since ancient times. It is an excellent source of protein, vitamins and minerals of the highest quality (DE MENDONÇA *et al.,* 2018). Besides providing protein of excellent standard, it is affordable to all layers of the population, and can contribute to improve the diet of low-income families. Due to its properties and great versatility, it is an extremely important component in the food sector. In addition to its use *in natura*, it is widely used as an ingredient in various foods (ALMEIDA *et al*., 2019; ORDÓÑEZ *et al*., 2019).

Generally, eggs have an average weight of 58 g and consist of 8 to 11% shell, 56 to61% white and 27 to 32% yolk (ORDÓÑEZ *et al*., 2019). The shell is formed by calcium carbonate (calcium carbonate crystals) and protein fibres (protein-mucopolysaccharide complex). It can have greater or lesser hardness according to the nutrition of the chicken and the amount of calcium contained in its diet (BELITZ *et al.,* 2012; ORDÓÑEZ *et al*., 2019).

Between the inner surface of the shell and the egg white, there are two membranes made of protein-polysaccharide fibers: an outer one, adhered to the shell, and an innerone, in direct contact with the white. They are very important, as they constitute a protective barrier against the penetration of bacteria. In addition, it is from the shell that gas exchange to the external environment occurs, and there may be alternation in the quality ofthe albumen and yolk (ORDÓÑEZ *et al*., 2019; JEZIUR & RUBIN, 2019).

Despite having all their constituents naturally protected by the shell, it is extremely important that their quality is maintained, since the time that elapses between laying, purchaseand use can be weeks. Soon after laying, the characteristics and quality of eggs begin to change as they are directly affected by temperature and environmental conditions, and this can be slowed by correct storage. This loss of quality that occurs during storage is seen differentlyby producers, consumers and food industries, which seek quality eggs with long shelf life (CAMPOS, 2018; DOS SANTOS, 2019).

During storage, eggs experience a series of modifications. The reduction in their internal quality is mainly associated with the loss of water and carbon dioxide during the storage period and is proportional to the increase in ambient temperature (BELITZ *et al.,* 2012; CAMPOS, 2018).

The transfer of water vapor through the shell causes the density to decrease (with initial value of approximately 1.086 $g.cm^{-3}$ and a daily decrease around 0.0017 $g.cm^{-3}$) and the airspace to increase. As a consequence of the decrease in viscosity of the egg white, the yolk rises, its spherical shape flattens out, and the surrounding membrane breaks easily when the egg is broken. The so-called "stale taste" is produced (BELITZ *et al.,* 2012; ORDÓÑEZ *et al*., 2019). One of the most important controls of external appearance is the one performed by ovoscopy, in which eggs are observed by translucidation, using a dark chamber with a pointof light, on which the eggs to be studied are arranged. Thus, characteristics of the shell, yolk, germ and air chamber are estimated (FREIRIA, 2017).

The food, industrialized or not, remains in constant biological activity, manifested by chemical, physical, microbiological or enzymatic changes, which lead to the deterioration of its quality. This loss of quality leads to an acceptability limit associated with its shelf life, that is, the period of time between the production and consumption of the product with a satisfactorylevel of quality (MOTA *et al.*, 2017).

Due to this fact, packages become important means of preserving the quality of food, playing an important role in maintaining its flavor and aroma (JORGE, 2013). They also serve as a barrier to water vapor, gases, aroma, and the migration of solutes between the food and the environment. In addition to protection, they offer convenience, maintenance of sensory quality and food safety (SOARES *et al.*, 2009; LUCENA *et al.*, 2017). However, despite all the advantages, food packaging has become a source of concern when disposed in the environment (JORGE, 2013).

The vast majority of packaging used in the food industry is still not biodegradable or recyclable, contributing to an overall increase in waste generation. As an alternative, biodegradable packaging materials are being developed. They can degrade by the action of microorganisms, reintegrating into nature more easily (SOUZA *et al.,* 2021). *Coatings* are an example of this type of packaging. In general, they have barrier and mechanical properties lower than plastic films, but can be consumed, and no waste is left in the environment in the long term, since they are biodegradable in their vast majority. Although coatings cannot fully replace synthetic film packaging, they have the potential to reduce the amount of synthetic/non-biodegradable packaging used (SOARES *et al.*, 2009; LUCENA *et al.*, 2017; CAMPOS, 2018).

The application of coatings to food extends its shelf life. The advantages of using these coatings are based on the fact that they act to minimize moisture migration, gas transport (CO_2 and O_2), solute transport, volatile aromatic compounds, and they also act as a vehicle for food additives, thus improving the quality of the food product (SOARES, 2009; HAN, 2014; MOTA *et al.*, 2017; CAMPOS, 2018).

Although the terms *films* and *coatings* are often used interchangeably, the basic difference is that films are pre-formed separately from the product. Coatings, on the other hand, are formed on the food surface itself, which can be done, for example, by immersion or sprinkling (SOARES *et al.*, 2009; HAN, 2014).

There are several types of dressings, with different properties regarding their resistance to gases or solute transport. As for their composition, they can be divided into three categories: hydrocolloids, which do not have excellent moisture barrier properties, but great barriers to oxygen, carbon dioxide and lipids. This category comprises proteins, including whey protein, obtained from bovine whey, which is a by-product of the dairy industry; lipids, which include waxes, fats and oils, among which palm oil stands out for not requiring hydrogenation and being highly stable to oxidation. Lipids are excellent to significantly reduce the transmission of water vapor due to their hydrophobic characteristics; and compounds, which may consist of a mixture of polysaccharides, proteins and/or lipids (HAN, 2014).

Given the above, the objective of the present work was to test the effect of coatings based on whey protein concentrate (WPSC), with and without the addition of a lipid source (palm oil), on the quality and mechanical resistance of chicken eggs.

MATERIAL AND METHODS

Material

The whey protein concentrate used in the coating solutions was Dairy-Pro 80 (80% protein), from the company ISP do Brasil Ltda./Germinal Aditivos para Alimentos, located in São Paulo, SP (Brazil). As a lipid source, refined palm oil from Agropalma, located in Belém, PA (Brazil), was used. Farm white chicken eggs (type 1 – extra), collected soon after laying, from Granja Avícola Nienow Ltda., located in Feliz, RS (Brazil), were used.

Eggs preparation

A total of 316 eggs were selected with the aid of an ovoscope, verifying aspects such as uniformity, centered yolks without developed germ, and absence of cracks in the shell, small clots or blood stains inside the eggs. They were sanitized in 1% sodium hypochlorite solution in water, remaining in the solution for 30 seconds. After this procedure, they were allowed to dry at room temperature.

Preparation and application of the coatings

The coating based on whey protein concentrate was prepared according to the methodology of Gennadios *et al*. (1993), with adaptations: 8% protein and 3.5% glycerol, completed with 100 g water ($w.w^{-1}$). The solution was homogenized until complete dissolution and submerged in water at 75º C for 50 minutes. Then, it was cooled down to 25º C, adjusting, if necessary,the pH to 7.0 with a 1.0 N NaOH solution. The palm oil used was heated to a temperature of 45º C and completely homogenized for subsequent application.

After selection and cleaning, the eggs were carefully placed on supports made with stainless steel wire, in a way that there were only three points of contact with the egg.Then, they were suspended on metal grids and positioned for storage.

The eggs were divided into three distinct groups:

A - Eggs without application of any type of coating;

B - Eggs with a coating based on whey protein concentrate;

C - Eggs with application of whey protein concentrate (left to dry) and subsequent application of palm oil.

For the application of coating B, the eggs were completely immersed in the WPC solution, with the help of their own support, for about 30 seconds. After coating, the eggs were placed in larger grids, where they were stored at room temperature (25 ± 2 ºC). For coating C, the eggs were completely immersed in the WPC solution for about 30 seconds. After coating, the eggs were placed on larger grids, where they were allowed to dry naturallyat room temperature. After drying, the eggs were immersed in a container with palm oil and stored again at room temperature.

Quality assessment

The following parameters were used to evaluate egg quality: weight loss, Haugh Unit and pH of the albumen. The determinations were made in triplicate (except for the weight loss, in which 6 samples were used) and followed during four weeks, in the periods of 0, 3, 7, 10, 14, 17, 22 and 24 days, since the objective of the study was to evaluate the influence of the coating over time, regardless of the shelf life of the product. No microbiological analyses were performed, because the intention was to verify the influence of the coatings on the quality characteristics that are mentioned below.

Weight loss

The weight loss was calculated by subtracting the final weight from the initial weight and dividing by the initial weight. The percentage was obtained by multiplying the values by 100, as shown in Equation 1.

$$(\%)\ PP = \frac{\left(P_i - P_f\right) * 100}{P_i} \qquad (1)$$

Where:
PP = weight loss; P_i = initial weight; and P_f = final weight.

Haugh Unit

To determine the Haugh unit, the eggs were broken on a level and smooth surface and the height of the albumen was measured as close as possible to the yolk with the aid of a caliper, previously adjusted to avoid measurement errors, with fixed support points and the same viewing angle for reading. Considering this, quality was calculated based on the Haugh unit equation (Equation 2).

$$UH = 100 * \log[H - \frac{\sqrt{G(30W^{0.37} - 100)}}{100} + 1.9] \qquad (2)$$

Where:
UH = Haugh unit; H = height of the thick white (mm); G = gravitational constant of value 32;W = egg weight (g).

pH Determination

The pH was determined according to the methodology described for eggs by Lanara (1981). The sample was suspended in deionized water in a 1:4 ratio and read directly in a Digimed pH meter, model DM-20.

Determination of mechanical resistance

To perform the determination of the mechanical resistance of the eggshell, about 100 eggs were subjected to specific density determination, so that all eggs used in the compression test obtained the same specific shell density. For this determination, solutions of sodium chloride (NaCl) with densities ranging from 1.065 to 1.100 (GREEN & SOUTHARD, 2018) were prepared at 0.05 intervals between solutions and placed in plastic buckets. Forty-eight eggs with the same specific density were selected. They were immersed in the solutionsstarting with the highest density, and those that floated were passed to the next solutions until they submerged. The solution in which this submersion occurred was determined as the specific density of the egg.

After determining the specific density, 8 samples of each group of eggs were used (eggs without coating, eggs with WPC coating and eggs with WPC + palm oil coating), and tests were performed on day zero and after 24 days of storage of eggs at room temperature (25 ºC ± 2 ºC). To perform the compression test, an Emic DL 2000 press was used, which is located in the Civil Engineering laboratory of the University of Vale do Rio dos Sinos(UNISINOS). The eggs were centered in the equipment with the help of a foam support, so that there was no interference between the egg and the surface of the equipment.

Statistical analysis

The results were statistically evaluated by the mean of treatments, analysis of variance (ANOVA) and Tukey's test at a 5% significance level ($p<0.05$), using the statistical program Statistica 6.0 (STATSOFT, 1998).

RESULTS AND DISCUSSION

After applying the coatings, the eggs presented an appearance similar to the original, with a slightly more accentuated shine, as shown in Figure 1.

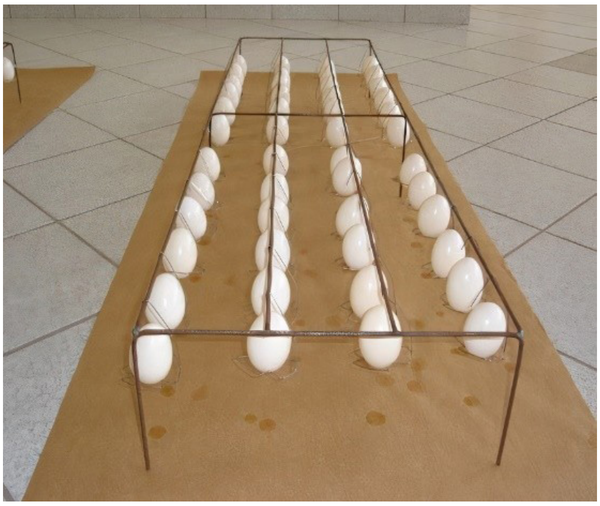

Figure 1. Eggs positioned on the supports, after application of the coatings

Weight loss

After determination of the weight loss, the analysis showed that this variable was affected by coating application during the storage time. Weight losses occurred in all eggs, being more prominent in the eggs without coatings. In the groups of eggs with coatings, it was noticed that the weight loss was lower over the storage time when compared to eggs without coatings (Figure 1). Among the eggs with coatings, the ones coated with WPC + palm oil were more efficient and had the lowest values for weight loss during storage (Figure 2).

The highest weight losses in the coated and uncoated egg groups are seen at day 24 (fourth week of storage), with values of 5.66% for uncoated eggs, 4.07% for those coated with WPC and 1.86% for those coated with WPC + palm oil, with significant difference ($p<0.05$). Caner and Yuceer (2015) obtained lower weight losses in eggs treated with whey protein, zeinand shellac coatings, relating this result to the ability of the coating to block the pores present in the eggshell. Mota *et al.* (2017), in turn, did not observe significant differences between the weight losses of eggs without coating and eggs coated with cassava starch and yam starch.

After 3 days of storage, the weight loss of uncoated eggs was 0.69%, whereas for eggs coated with WPC and WPC + palm oil the values were 0.5% and 0.29%, respectively, without significant

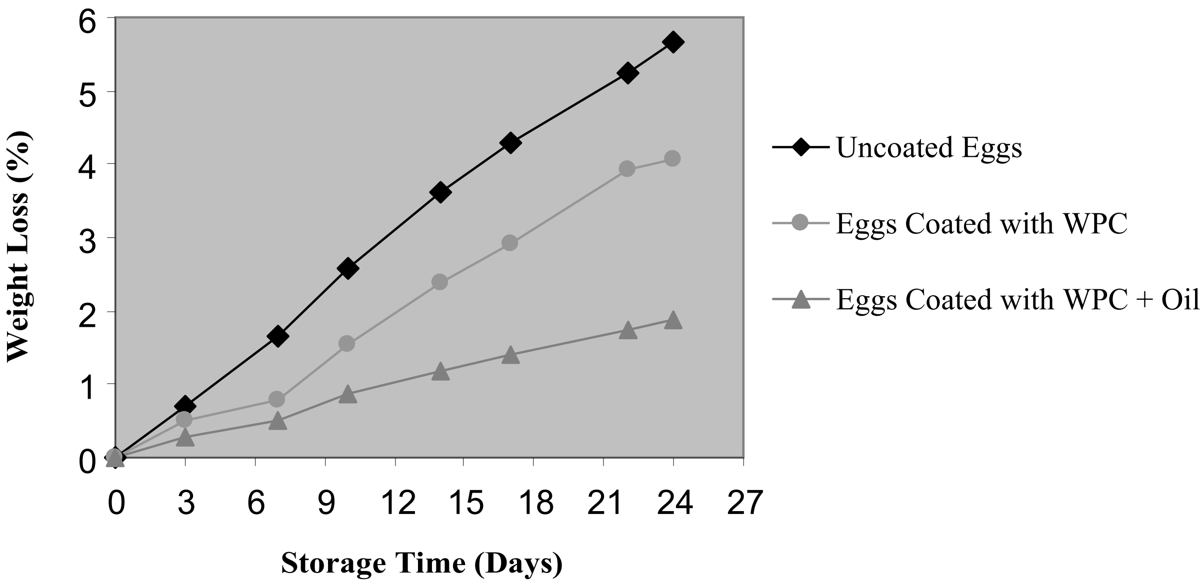

Figure 2. Weight loss of uncoated and coated eggs as a function of storage time

differences between these days. At 17 days of storage, the uncoated eggs already showed 4.24% weight loss, while the eggs coated with WPC and WPC + palm oil showed values of 2.92% and 1.40%, respectively.

It is possible that the weight loss of WPC-coated eggs is related to bovine whey protein and glycerol. Bovine whey protein has hydrophilic amino acid residues that allow water molecules to pass through. Glycerol (used to provide uniformity in the coating) can improve the mechanical properties of the film, but can also impair barrier properties. (DE PAULA, 2016).

The use of palm oil as a component of one of the coatings provided an efficient water vapor barrier, probably due to being highly hydrophobic. Also, the fact that this type of oil has a high saturated fat content may have contributed to this efficiency, since according to De Paula (2016), films composed of lipids can have good water vapor barrier properties. Thus, coatings with higher amounts of saturated fat have better barrier properties than those with higher amounts of polyunsaturated fat. This is explained considering the relative solubility of water vapor in the liquid lipid and solid lipid phases, and/or the molecular organization of the lipid.

Haugh unit

In the experiment, there was a decrease in the Haugh unit for both uncoated and coated eggs throughout the 24 days of storage. Lower values were observed for the uncoated eggs (Figure 3).

After 3 days of storage, the Haugh unit was 86 HU for uncoated eggs, 84 HU for eggs coated with WPC and 80 HU for eggs coated with WPC + palm oil, without significant differences ($p>0.05$). The HU values for the respective groups of eggs, after 10 days of storage, were 64, 72 and 73 HU, with significant difference ($p<0.05$). This decrease in Haugh unit values represents a decline in egg quality.

At 14 days there is an evident decrease in the HU of the WPC-coated eggs, which continues until day 22 (from 74 to 62 HU), where it starts to stabilize. The eggs coated with WPC + palm oil show a more stable behavior, which is observed from day 10 to day 22 (Figure 2).

In their study, Mota *et al*. (2017) coated eggs with cassava starch and yam starch. After 28 days of storage, eggs treated with these coatings showed greater reduction in HU values, corroborating with the results found. Furthermore, the values of 63 and 61 HU found in this study, for eggs coated with WPC and WPC + palm oil, may indicate the classification of eggs as type A, according to Yuceer and Caner (2014).

Campos (2018) evaluated the Haugh unit values as a quality measure for eggs coated with babassu meal and oil, obtaining values of 56 and 58 HU at the end of a 28-day storage period. In this experiment, at the end of 22 days, with

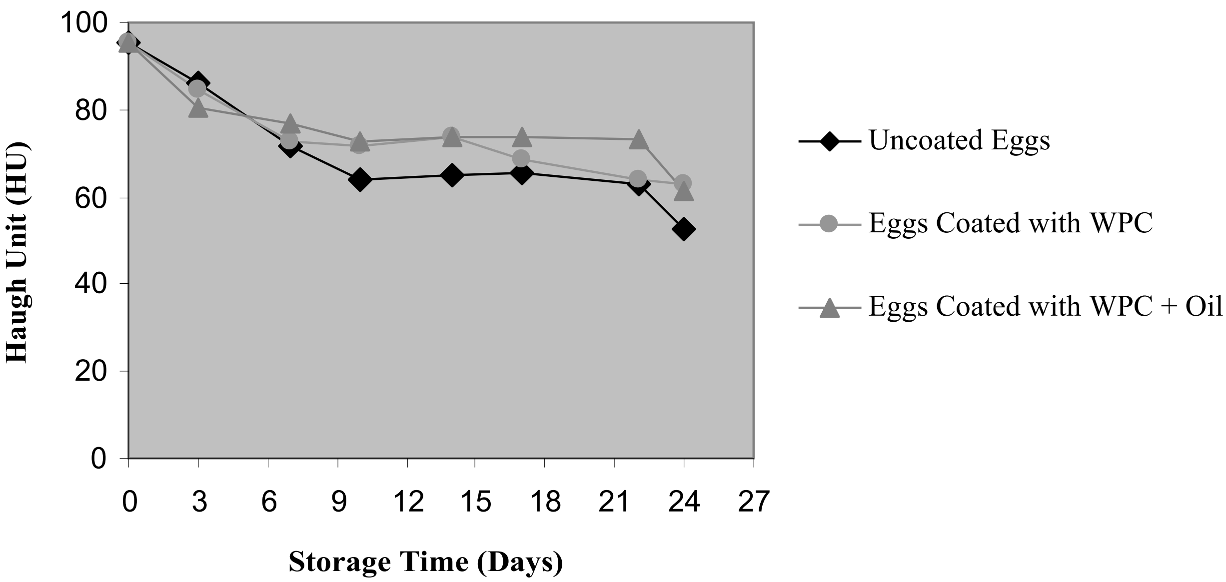

Figure 3. Haugh unit of coated and uncoated eggs as a function of storage time

storage at room temperature, the values obtained were 63, 64 and 73 HU, for uncoated eggs, eggs coated with WPC and coated with WPC + palm oil, respectively, with significant difference among the groups ($p<0.05$). At the end of 22 days of storage, the uncoated eggs and the WPC-coated eggsobtained similar results.

According to Morsy *et al*. (2015), the decrease in HU values occurs due to protein denaturation resulting from pH change during egg storage. However, it is noted that the presence of coatings delayed the decrease in HU, with reductions of 45, 34 and 34% for uncoated eggs, eggs coated with WPC and coated with WPC + palm oil, respectively, when compared to day-old eggs.

pH determination

Fresh and quality eggs present neutral pH, and their whites are clear, transparent, consistent, dense and high. As the eggs age, the pH of albumen increases due to the mixing of carbonic acid, forming water and carbonic gas (FIGUEIREDO *et al*., 2011). In the experiment, the pH of uncoated eggs, in general, showed higher values than coated ones (Figure 4).

In uncoated eggs, the pH ranged from 9.67 to 9.81 in four weeks of storage. Eggs coated with WPC ranged from 9.20 to 9.76 and those coated with WPC + palm oil ranged from 9.01 to 9.30, showing the lowest pH values at the end of 24 days of storage. Mota *et al.* (2017) observed that the albumin of eggs coated with yam starch and cassava starch, stored for 28 days at room temperature, showed pH of 9.08 and 9.22, respectively. Eggs coated with WPC + palm oil had a decrease in pH during storage; still, the other two groups of eggs (uncoated and coated with WPC) also showed an increase in pH over time, until 17 days of storage.

In the study of Campos (2018), it was observed that the eggs had a slight decrease in pH, and at the end of 28 days, the eggs without the application of any treatment had a pH of 9.2, while the eggs with treatments maintained pH values of 8.4 to 8.5. In eggs stored under refrigeration there was more stability, and at the end the pH was around 8.6 for all treatments. In the experiment, we observed that eggs coated with WPC + mineral oil had an inverse behavior, with a decline in pH until day 22. The uncoated and WPC-coated eggs had an increase in pH until day 17 (Figure 3). It is observed that from day 17 the uncoated and WPC-coated eggs did not differ significantly ($p>0.05$) until day 24. The eggs withWPC + palm oil had decrease in pH from this day on.

According to the literature cited (BELITZ *et al.,* 2012; ORDÓÑEZ *et al*., 2019) the increase in pH occurs due to the loss of carbon dioxide through the pores of the shell, which causes a breakdown of the gel structure characteristic of the dense layer of albumen. This causes the albumen to lose consistency or viscosity, therefore losing quality.

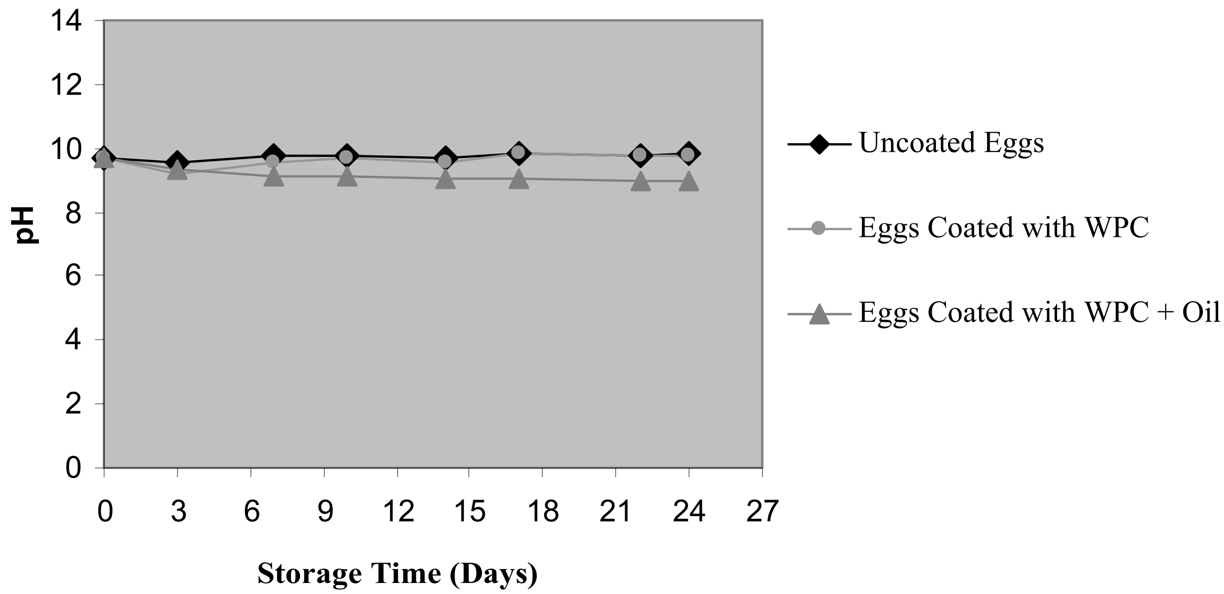

Figure 4. pH of albumen from coated and uncoated eggs as a function of storage time

WPC had an important effect in controlling pH, working as a barrier that prevented the loss of CO_2 from coated eggs. The lipid used in one of the coatings made this barrier more efficient against the loss, even making the pH more stable when compared to the other groups of eggs. The greater the loss of CO_2, the greater the alkalinity of the egg albumen, and consequently the lower the internal quality of the egg.

Determination of mechanical resistance

The specific density of the 48 eggs was determined to be 1.095. The higher thespecific density of eggs, the better the shell quality. This is because density is directly related to egg shell thickness: the higher the density, the thicker the shell.

The results obtained in the compression test (Figure 5) show that the eggs with WPC + oil obtained the best results: at the end of 24 days of storage, the maximum force applied was 19.00% higher compared to the uncoated eggs and 9.43% higher in eggs coated with WPC.

At day zero, the uncoated eggs obtained a force value of 25.62 N, while eggs coated with WPC and WPC + oil obtained 29.49 and 30.28 N, respectively. At day 24, uncoated eggs obtained 26.60 N and those coated with WPC and WPC + oil obtained values of 28.32 N and 30.98 N, respectively.

Coated eggs obtained better results than uncoated ones. In the experiment, the presence of a lipid combined with a protein worked as a barrier to moisture and CO_2. This made the coating present lower values for weight loss and pH, as well as higher values for Haugh unit and shell strength, thus characterizing better quality eggs in the mentioned storage time.

CONCLUSION

- The application of coating on eggs reduced their weight loss throughout the 24 days of storage. Considering both groups of coated eggs, the loss was lower for those coated with WPC + palm oil at the same storage time. Regarding pH, eggs coated with WPC + oil also showed lower values when compared to the other two groups, at the end of 24 days. In the experiment, there was a decrease inthe Haugh unit for all groups, being more evident in the uncoated eggs throughout storage.
- Coated eggs showed higher shell strength values, and the eggs with palm oil showed the best results at the same storage time. Therefore, in this study the coating that offered the lowest loss of quality of eggs, during 24 days of storage, was the coating of WPC + oil.

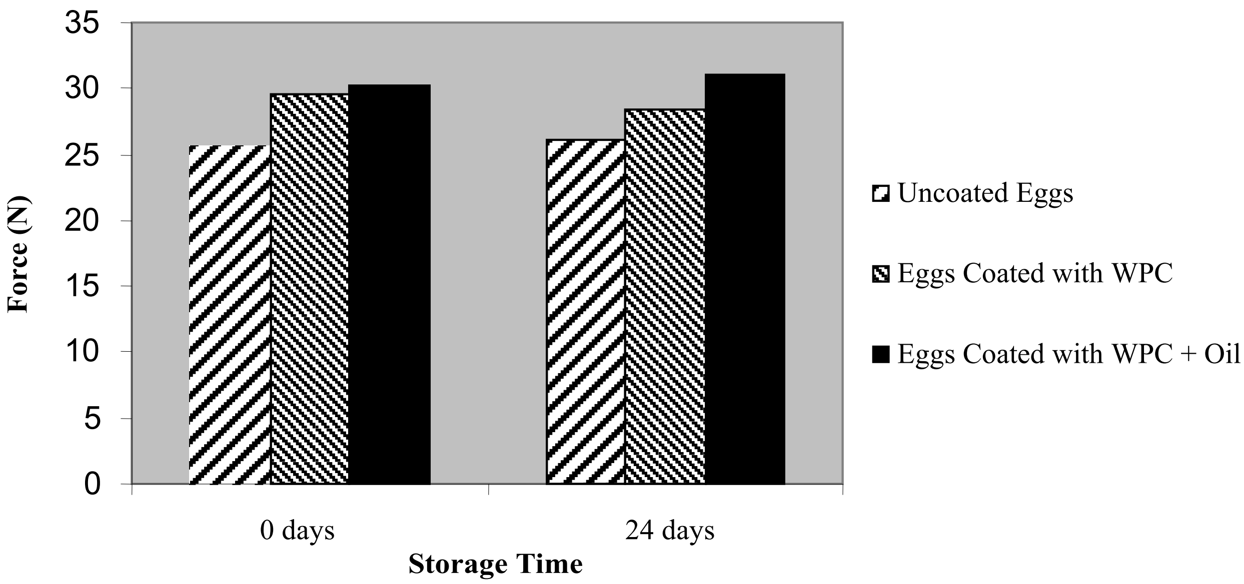

Figure 5. Force obtained as a function of storage time

AUTHORSHIP CONTRIBUTION STATEMENT

LOPES, L.C.: Formal Analysis, Resources, Software, Visualization, Writing – review & editing; **SILVA, A.O.:** Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft; **LUVIELMO, M.M.:** Data curation, Funding acquisition, Project administration, Supervision, Validation.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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