Acta Alimentaria 51 (2022) 4, 605–612
DOI: 10.1556/066.2022.00180

AKADÉMIAI KIADÓ

Rice, soy, and whey protein coatings as carriers to extend egg shelf life

P.G.d.S. Pires[1*], C. Bavaresco[2], G.d.S. Oliveira[3], C. McManus[3], V. Machado dos Santos[4] and I. Andretta[1]

[1] Department of Animal Science, Universidade Federal do Rio Grande do Sul, Bento Gonçalves 7712, Porto Alegre, Brazil

[2] Zootechnician, Non-ruminants Nutrition, Animal Science, Brazil

[3] Faculty of Agronomy and Veterinary Medicine, University of Brasília, Brasília, Federal District, Brazil

[4] Laboratory of Poultry Science, Federal Institute of Brasília, Brasília, Federal District, Brazil

ORIGINAL RESEARCH PAPER

Received: September 6, 2022 • Accepted: November 3, 2022
Published online: November 30, 2022
© 2022 Akadémiai Kiadó, Budapest

ABSTRACT

This study aimed to compare and evaluate the effects of different protein coatings on maintaining the quality of eggs stored for six weeks at 20 °C. 308 brown table eggs from ISA Brown hens were used for four treatments: uncoated eggs, coated with rice protein concentrate – RPC, soy protein concentrate – SPC, and whey protein concentrate – WPC. Eggs started with Haugh Units (HU) of 82.01 and reduced in proportions of 28.75% (control), 12.82% (RPC), 12.90% (SPC), and 10.54% (WPC) on the last day of storage. Coated eggs showed smaller reductions ($P < 0.0001$) in this response. Protein coatings can effectively maintain the quality of eggs stored for six weeks at 20 °C. However, the WPC coating maintained the highest egg rate and the best yolk index for eggs stored for six weeks at 20 °C.

KEYWORDS

eggshell, egg storage, egg safety, internal egg quality, protein coatings

* Corresponding author. E-mail: paulagabrielapires@yahoo.com.br

AKJournals

1. INTRODUCTION

High-quality eggs provide a high financial return for the egg industry and the establishments that market them, as well as being healthy and safe for human consumption. Room temperature is a villain in the maintenance of egg quality. This is corroborated by the higher egg weight loss, Haugh unit, albumen and yolk pH, and yolk index in eggs stored at room temperature in comparison with those stored under refrigeration (Akter et al., 2014; Oliveira et al., 2020; Martínez et al., 2021; Yamak et al., 2021). Coatings are allies in preserving the quality of eggs stored at room temperature (Oliveira et al., 2020).

Egg coating is an applied solution that coats the entire eggshell and can be made from chitosan, pectin, starch, gum arabic, and resin (Oliveira et al., 2020, 2022; Akarca et al., 2021; Derelioglu and Turgay, 2022; Sariyel et al., 2022). The positive effects of the use of the film depend on the ability of the material to form a good-quality coating (Pires et al., 2022). Proteins are good film-formers, presenting excellent barrier properties to oxygen, CO_2, and lipids, particularly at low relative humidity (Lacroix and Vu, 2014). In addition, protein-based coatings can be a sustainable option. Soybean protein concentrate is available in a commercial form, contains more than 90% protein, and showed favourable results when used as egg coating (Xu et al., 2017). Whey protein originating from the liquid left over when milk is coagulated (curdled) during cheese making, can also be a good alternative (Caner and Yüceer, 2015). Rice protein has repercussions in the global context, as it originates from one of the most produced crops in the world (Pires et al., 2019b). The objective of this study was to compare and evaluate the effects of protein coatings (rice protein concentrate – RPC, soy protein concentrate – SPC, and whey protein concentrate – WPC) in maintaining the quality of eggs stored for six weeks at 20 °C.

2. MATERIALS AND METHODS

308 brown table eggs from ISA Brown hens were obtained from a commercial poultry farm. Eggs were divided (77 each) into a control group (uncoated eggs) and groups coated with RPC (MidWay Labs, FL, USA), WPC (Lacprodan® 80, SP, Brazil), and SPC (Selecta, GO, Brazil).

The coating formulation consisted of continuous stirring (90 °C for 30 min) of 8% RPC, WPC, or SPC (w/w) and 4% glycerol (w/w) in distilled water (1,000 mL) (Antunes, 2003). The final pH was adjusted to 10.0 using 1N NaOH. Simultaneously with the preparation of the coating solution, each egg was immersed in clean water at 42 °C (washed with brushes simulating the industrial process to remove any dirt) and in chlorine at 50 ppm (to avoid any harmful microbial impact) and dried for five min. Before being stored for 42 consecutive days (six weeks) at 20 °C (storage chamber monitored by a digital thermostat for 24 h a day until the end of the experiment), each egg was immersed in the protein coatings at 24 °C (one min), dried for 20 min on a metal grid, and then placed in sanitised trays identified according to each treatment.

On the same day they were coated, the initial internal quality a total of 20 eggs was evaluated based on the Haugh unit (HU), yolk index (YI), albumen, and yolk pH to show that there was no difference between treatments. Subsequently, these same analyses were performed at intervals of seven days until the sixth week of storage, plus weight loss in 12 eggs per treatment. Eggs had similar initial average weight ($P > 0.05$), with uncoated eggs 68.11 ± 0.5 g, RPC 69.37 ± 0.5 g, SPC 69.15 ± 0.5 g, and WPC 69.03 ± 0.5 g.

Egg weight loss was obtained by the difference between the initial and final egg weight (recorded with a 0.0001 g precision scale (Gehaka, São Paulo, São Paulo, Brazil)) divided by the initial egg weight and multiplied by 100.

The HU was obtained by HU = 100 log(albumen height + 7.57 – 1.7 × egg weight$^{0.37}$) (Haugh, 1937). Albumen height was recorded after measurement on a flat surface using a digital calliper with 0.001-mm precision (Mitutoyo, Suzano, São Paulo, Brazil).

The YI was obtained by dividing the yolk height by its diameter (Funk, 1948) after being separated from the albumen. The variables were measured on a flat surface using the above digital calliper.

Individually, albumen and yolk pH values were obtained using a digital pH meter (206–pH2, Testo®, Lenzkirch, Baden-Württemberg, Germany).

A completely randomised design was used in the study. Statistical procedures were performed using the software Minitab 18 (Minitab Inc., State College, PA). Each egg was considered an experimental unit. The statistical model included the effects of treatments (coating types), storage periods (weeks), and interaction between factors (treatments by storage periods), according to model:

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

Where:

μ: average overall; di: effects of treatments (i: 1–4); weeks: fixed effect of storage periods (k = 1–6; weight loss) (k: 0–6; HU, YI, albumen and yolk pH); dwjk: fixed effect of the interaction between treatment and storage periods (treatment × storage period); eijk: random error (residual error).

After the analysis of variance (ANOVA), significant differences ($P < 0.05$) were assessed with Tukey's multiple comparison test.

3. RESULTS AND DISCUSSION

There was a higher weight loss ($P < 0.0001$) in uncoated eggs (5.37%) than in coated eggs at the sixth week of storage (Fig. 1). Protein coatings reduced egg weight loss by 1.28% (RPC), 1.08% (SPC), and 1.34% (WPC), keeping it within the acceptable range up to 4 weeks of storage. However, eggs coated with RPC and WPC showed less weight loss compared to SPC. The whey protein has hydrophilic amino acid residues in its composition and glycerol provides a uniform

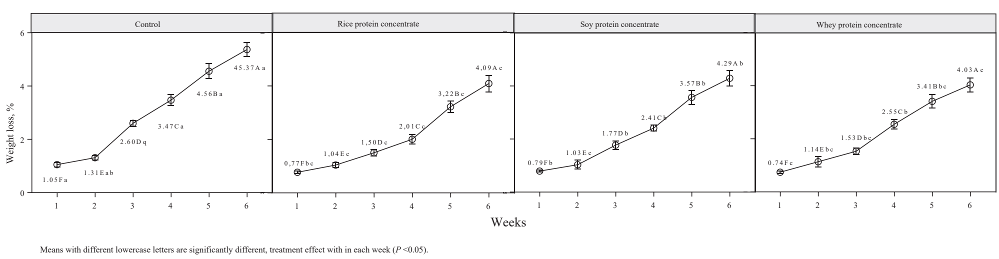
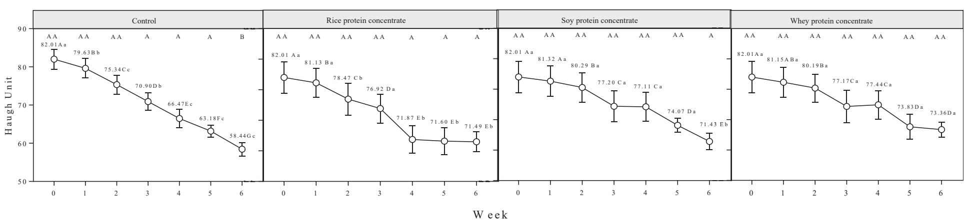


Fig. 1. Effect of different protein coatings on weight loss of eggs stored for six weeks at 20 °C

coating with whey protein, by breaking the hydrogen chains, resulting in less weight loss for the coated eggs. The same can be expected for coatings made with rice protein. The coatings produced a protective structure against unwanted water and carbon dioxide losses, preserving the internal integrity of the egg. This benefit was also previously observed when eggs were coated with the same coatings (Almeida et al., 2016; Xu et al., 2017; Pires et al., 2019a) and other coatings such as pectin and cassava starch plus essential oils (Oliveira et al., 2020, 2022).

Eggs started with HU of 82.01 and reduced in proportions of 28.75% (control), 12.82% (RPC), 12.90% (SPC), and 10.54% (WPC) by the last day of storage (Fig. 2). The reduction in HU (linked to reduced egg quality) may be due to disruption of the ovomucin-lysozyme complex in the albumen (Yüceer and Caner, 2014). This disruption, influenced by the time and temperature of egg storage, should be delayed as seems to be the case with the coated eggs, as they generated smaller reductions ($P < 0.0001$). Analysing the eggs according to Yüceer and Caner (2014), only the WPC coating maintained the highest egg grade (AA, HU > 72), followed by the RPC and SPC coatings (egg grade in A; HU = 71–60) and uncoated eggs (egg grade B; HU = 59–31). This result is possibly due to the better adhesion and coverage provided by the



Egggrades: AA, HU > 72; A, HU = 71—60; B, HU = 59 < 31; C, HU < 30.
Means with different lower case letters are significantly different, treatment effect with in each week ($P < 0.05$).
Means with different capital letters are significantly different, week effect with in eacht reatment ($P < 0.05$).

Fig. 2. Effect of different protein coatings on the Haugh unit (HU) and grade of eggs stored for six weeks at 20 °C

Table 1. Effect of different protein coatings on the yolk index (YI) of eggs stored for six weeks at 20 °C

Week	Control (Uncoated eggs)	Protein coating		
		RPC	SPC	WPC
0	0.48 ± 0.01^{Aa}	0.48 ± 0.01^{Aa}	0.48 ± 0.01^{Aa}	0.48 ± 0.01^{Aa}
1	0.44 ± 0.01^{Bb}	0.45 ± 0.01^{Ba}	0.45 ± 0.01^{Ba}	$0,45 \pm 0.01^{Ba}$
2	0.40 ± 0.01^{Cc}	0.45 ± 0.01^{Ba}	0.41 ± 0.01^{Cbc}	0.44 ± 0.01^{Cb}
3	0.38 ± 0.01^{Dd}	0.42 ± 0.01^{Cb}	0.40 ± 0.01^{Dc}	0.44 ± 0.01^{Ca}
4	0.37 ± 0.01^{Eb}	0.41 ± 0.01^{CDa}	0.38 ± 0.01^{Eb}	0.42 ± 0.01^{Da}
5	0.36 ± 0.01^{Ec}	0.40 ± 0.01^{Db}	0.38 ± 0.01^{Fc}	0.42 ± 0.01^{Da}
6	0.33 ± 0.01^{Fd}	0.38 ± 0.01^{Eb}	0.37 ± 0.01^{Gc}	0.40 ± 0.01^{Ea}

Statistical model included the effects of treatments ($P < 0.001$), storage periods ($P < 0.001$), and interaction (treatments by storage periods, $P < 0.001$).
RPC: Rice protein coating; SPC: Soybean protein coating; WPC: Whey protein coating.
$^{a-d}$: Means in the same row with different lowercase letters are significantly different ($P < 0.05$).
$^{A-G}$: Means in the same column with different capital letters are significantly different ($P < 0.05$).

Table 2. Effect of different protein coatings on albumen and yolk pH of eggs stored for six weeks at 20 °C

Week	Albumen pH				Yolk pH			
	Control (Uncoated eggs)	Protein coating			Control (Uncoated eggs)	Protein coating		
		RPC	SPC	WPC		RPC	SPC	WPC
0	8.05 ± 0.11^{Ea}	8.05 ± 0.11^{Ca}	8.05 ± 0.11^{Ea}	8.05 ± 0.11^{Ca}	6.27 ± 0.05^{Ca}	6.27 ± 0.05^{Ca}	6.27 ± 0.05^{Ca}	6.27 ± 0.05^{CDa}
1	8.37 ± 0.13^{Da}	8.14 ± 0.12^{BCb}	8.09 ± 0.08^{Eb}	8.07 ± 0.04^{Cb}	6.45 ± 0.03^{BCa}	6.32 ± 0.02^{Cab}	6.09 ± 0.02^{Cbc}	6.06 ± 0.05^{Dc}
2	8.70 ± 0.10^{Ca}	8.24 ± 0.09^{Bc}	8.37 ± 0.08^{Db}	8.25 ± 0.20^{Bc}	6.57 ± 0.04^{Bab}	6.45 ± 0.06^{BCb}	6.51 ± 0.10^{BCab}	6.78 ± 0.09^{Aba}
3	9.09 ± 0.22^{Ba}	9.11 ± 0.15^{Aa}	8.47 ± 0.12^{Cb}	9.09 ± 0.19^{Aa}	6.91 ± 0.07^{Aa}	6.45 ± 0.05^{BCb}	6.94 ± 0.05^{ABa}	6.61 ± 0.07^{BCab}
4	9.21 ± 0.19^{Ba}	9.22 ± 0.15^{Ab}	9.09 ± 0.16^{Bb}	9.16 ± 0.14^{Aab}	6.96 ± 0.04^{Aab}	6.46 ± 0.02^{BCb}	7.07 ± 0.09^{ABa}	7.16 ± 0.10^{Aa}
5	9.43 ± 0.21^{Aa}	9.25 ± 0.16^{Ab}	9.16 ± 0.15^{ABb}	9.15 ± 0.18^{Ab}	6.97 ± 0.10^{Aa}	6.71 ± 0.014^{ABb}	7.27 ± 0.12^{Aa}	6.63 ± 0.09^{Cb}
6	9.50 ± 0.30^{Aa}	9.15 ± 0.17^{Ac}	9.21 ± 0.27^{Abc}	9.15 ± 0.13^{Ac}	7.00 ± 0.12^{Aab}	6.78 ± 0.07^{Ab}	7.19 ± 0.20^{Aa}	7.19 ± 0.17^{Aa}

Statistical model included the effects of treatments ($P < 0.001$), storage periods ($P < 0.001$) and interaction (treatments by storage periods, $P < 0.001$).
RPC: Rice protein coating; SPC: Soybean protein coating; WPC: Whey protein coating.
$^{a-c}$: Means in the same row with different lowercase letters are significantly different ($P < 0.05$).
$^{A-E}$: Means in the same column with different capital letters are significantly different ($P < 0.05$).

WPC to the eggs. Lopes et al. (2022) reported that eggs coated with WPC or WPC plus palm oil had higher HU values at 24 days of storage at 25 ± 2 °C than uncoated eggs.

The YI changes depend on how much water from the albumen (resulting from its degradation) moves into the yolk making it more liquefied (Obanu and Mpieri, 1984). The greater this movement, the worse is the quality of the yolk. Uncoated eggs had the lowest YI ($P < 0.0001$) at the end of the experiment, equivalent to a 31.25% decrease compared to week 0, followed by coated eggs (RPC, 20.83%; SPC, 22.92%; WPC, 16.67%) (Table 1). Eggs coated with SPC showed values similar to uncoated eggs at the 2nd, 4th, and 5th week. In the following weeks, the protein coatings provided averages superior to the control. From the 2nd week, RPC and WPC showed the highest YI, and at the end of storage, the best YI was observed for WPC, followed by RPC and SPC. There are oscillations of the best results between RPC and WPC. Protein coatings maintained yolk quality throughout storage. Other coating materials showed similar results. For example, Derelioglu and Turgay (2022) reported that eggs coated with chitosan had significantly higher yolk index compared to uncoated eggs during storage for four weeks at 24 ± 2 °C.

Over the storage period, albumen pH increased from 8.05 to 9.50 (control), 9.15 (RPC), 9.21 (SPC), and 9.15 (WPC) at the end of storage (Table 2). All protein coatings had a significantly lower albumen pH ($P < 0.0001$) than the uncoated eggs. Khattak et al. (2016) showed that the pH of eggs coated with soy protein was significantly higher than that of uncoated eggs. The flow of CO_2 from the inside to the outside of the egg appears to be an important cause of the increase in albumen pH and poor egg quality (Biladeau and Keene, 2009). Therefore, a higher albumen pH reflects a reduction in egg quality. We confirm that coating protein solutions have a semi-permeable blocking capacity that controls the flow of CO_2. There was no significant difference ($P > 0.05$) between coated and uncoated eggs for yolk pH ranging from 6.27 to 7.00 (control), 6.78 (RPC), 7.19 (SPC), and 7.19 (WPC). This work demonstrates that it is possible to use coatings to increase egg shelf life by using protein-based coatings. Coatings can be a sustainable alternative for maintaining egg quality (HU, YI, and pH) that is adversely affected by the length of storage.

4. CONCLUSIONS

Protein coatings can effectively maintain the quality of eggs stored for six weeks at 20 °C. Although SPC benefited the eggs' internal integrity, it performed less well than other coatings. RPC and WPC had better barrier quality, reducing the rate of egg weight loss during storage. However, WPC showed superiority in preserving the quality integrity of eggs (highest HU (AA) and the best YI), this result can be related to the chemical structure of WPC, making the coating more efficient for storage. Thus, it is recommended to coat eggs stored for up to 42 days with WPC.

ACKNOWLEDGMENT

We thank Conselho Nacional de Desenvolvimento Cientíifico e Tecnológico (CNPq) for the PhD scholarship. Arla Foods Ingredients S.A. for the donation of the WPC. We also thank Granja Filippsen for the donation of the eggs.

REFERENCES

Akarca, G., Istek, Ö., and Tomar, O. (2021). The effect of resin coating on the quality characteristics of chicken eggs during storage. *Journal of Food Science*, 86(4): 1243–1257. https://doi.org/10.1111/1750-3841.15686.

Akter, Y., Kasim, A., Omar, H., and Sazili, A.Q. (2014). Effect of storage time and temperature on the quality characteristics of chicken eggs. *Journal of Food, Agriculture and Environment*, 12(3–4): 87–92.

Almeida, D.S.D., Schneider, A.F., Yuri, F.M., Machado, B.D., and Gewehr, C.E. (2016). Egg shell treatment methods effect on commercial eggs quality. *Ciência Rural*, 46: 336–341.

Antunes, A.J. (2003). *Funcionalidade de proteínas do soro de leite bovino*. Editora Manole Ltda, p. 135.

Biladeau, A.M. and Keener, K.M. (2009). The effects of edible coatings on chicken egg quality under refrigerated storage. *Poultry Science*, 88(6): 1266–1274. https://doi.org/10.3382/ps.2008-00295.

Caner, C. and Yüceer, M. (2015). Efficacy of various protein-based coating on enhancing the shelf life of fresh eggs during storage. *Poultry Science*, 94(7): 1665–1677. https://doi.org/10.3382/ps/pev102.

Derelioglu, E. and Turgay, O. (2022). Effect of chitosan coatings on quality and shelf-life of chicken and quail eggs. *African Journal of Food Science*, 16(3): 63–70. https://doi.org/10.5897/AJFS2021.2158.

Funk, E. (1948). The relation of the yolk index determined in natural position to the yolk index as determined after separating the yolk from the albumen. *Poultry Science*, 27(3): 367.

Haugh, R.R. (1937). A new method for determining the quality of an egg. *US Egg Poultry*, 39: 27–49.

Khattak, A., Sharma, M., and Sanghi, D. (2016). Extension of shelf life of raw eggs using whey protein based eggshell coating. *International Journal of Food and Nutritional Sciences*, 5(3): 80.

Lacroix, M. and Vu, K.D. (2014). Edible coating and film materials: proteins. In: Han, J.H. (Ed.), *Innovations in food packaging*. Elsevier, pp. 277–304.

Lopes, L.C., da Silva, A.O., and Luvielmo, M.M. (2022). Evaluation of the quality and mechanical resistance of eggs with the application of biodegradable coatings. *Revista Engenharia na Agricultura – REVENG*, 30: 75–84. https://doi.org/10.13083/reveng.v30i1.13214.

Martínez, Y., Soliz, N.D., Bejarano, M.A., Paz, P., and Valdivie, M. (2021). Effect of storage duration and temperature on daily changes in external and internal egg quality of eggs from Dekalb White® laying hens. *European Poultry Science*, 85. https://doi.org/10.1399/eps.2021.329.

Obanu, Z.A. and Mpieri, A.A. (1984). Efficiency of dietary vegetable oils in preserving the quality of shell eggs under ambient tropical conditions. *Journal of the Science of Food and Agriculture*, 35(12): 1311–1317. https://doi.org/10.1002/jsfa.2740351207.

Oliveira, G.S., dos Santos, V.M., Rodrigues, J.C., and Santana, Â.P. (2020). Conservation of the internal quality of eggs using a biodegradable coating. *Poultry Science*, 99(12): 7207–7213. https://doi.org/10.1016/j.psj.2020.09.057.

Oliveira, G.D.S, McManus, C., Pires, P.G. D.S., and dos Santos, V.M. (2022). Combination of cassava starch biopolymer and essential oils for coating table eggs. *Frontiers in Sustainable Food Systems*, 6: 957229. https://doi.org/10.3389/fsufs.2022.957229.

Pires, P.G.S., Bavaresco, C., Wirth, M.L., and Moraes, P.O. (2022): Egg coatings: trends and future opportunities for new coatings development. *World's Poultry Science Journal*, 78(3): 751–763. https://doi.org/10.1080/00439339.2022.2075298.

Pires, P.G.S., Machado, G.S., Franceschi, C.H., Kindlein, L., and Andretta, I. (2019a). Rice protein coating in extending the shelf-life of conventional eggs. *Poultry Science*, 98(4): 1918–1924. https://doi.org/10.3382/ps/pey501.

Pires, P.G.S., Pires, P.D.S., Cardinal, K.M., Leuven, A.F.R., Kindlein, L., and Andretta, I. (2019b). Effects of rice protein coatings combined or not with propolis on shelf life of eggs. *Poultry Science*, 98(9): 4196–4203. https://doi.org/10.3382/ps/pez155.

Sariyel, V., Aygun, A., Coklar, H., Narinc, D., and Akbulut, M. (2022). Effects of prestorage application of gum arabic coating on the quality of table eggs during storage. *Kafkas Universitesi Veteriner Fakultesi Dergisi*, 28: 363–370. https://doi.org/10.9775/kvfd.2022.27077.

Xu, L., Zhang, H., Lv, X., Chi, Y., Wu, Y., and Shao, H. (2017). Internal quality of coated eggs with soy protein isolate and montmorillonite: Effects of storage conditions. *International Journal of Food Properties*, 20(8): 1921–1934. https://doi.org/10.1080/10942912.2016.1224896.

Yamak, U.S., Sarica, M., Erensoy, K., and Ayhan, V. (2021). The effects of storage conditions on quality changes of table eggs. *Journal of Consumer Protection and Food Safety*, 16: 71–81. https://doi.org/10.1007/s00003-020-01299-6.

Yüceer, M. and Caner, C. (2014). Antimicrobial lysozyme-chitosan coatings affect functional properties and shelf life of chicken eggs during storage. *Journal of the Science of Food and Agriculture*, 94(1): 153–162. https://doi.org/10.1002/jsfa.6322.