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Application of tamarind kernel polysaccharide-soybean oil emulsion coating to preserve the internal quality and extend shelf-life of fresh eggs

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Abstract

A tamarind kernel polysaccharide (TKP)-soybean oil (SO) emulsion coating was developed to study the effects of the coating on internal quality and shelf-life of fresh eggs. The efficiency of polysaccharide-based coating on fresh egg quality during 35 d storage at 25 °C was evaluated in terms of Haugh unit, weight loss, albumen pH, yolk pH and yolk index. Non-coated eggs served as the control. TKP-SO emulsions and SO-coated eggs maintained A grade up to 21 d of storage, while non-coated and TKP-coated eggs degraded from AA to B grade after 7 and 14 d, respectively. Weight loss of eggs coated with TKP-SO emulsion was significantly ($p \leq 0.05$) lower than that of non-coated eggs and eggs coated with TKP. The highest weight loss was obtained for the non-coated eggs with 5.67% after 35 d storage, while the value increased from the initial day of storage by 5.13, 2.29, 2.38 and 0.54% for TKP, TKP-SO10, TKP-SO30 and SO, respectively. SO coating exhibited high moisture barrier efficiency but application required a long drying period. The pH in albumen of non-coated eggs and eggs coated with TKP increased from 8.93 and 8.82 to 9.42 and 9.14, respectively, after 35 d of storage. Higher yolk index was observed in the TKP-SO emulsions coated egg compared to TKP-coated eggs and non-coated eggs throughout the storage period. This study indicated that the biopolymer coatings from TKP-SO emulsion at ratios of 10:90 and 30:70 had high potential to preserve the internal quality of coated-eggs during 35 d of storage at 25 °C compared to TKP and control treatment. The TKP-SO emulsion coatings are promising a commercial biodegradable coating for extending the shelf life of fresh eggs.

Keywords: *biopolymer, emulsion coating, fresh eggs, shelf-life, soybean oil, tamarind kernel polysaccharide*

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1. Introduction

Biopolymer films and coatings are currently receiving increasing attention as they offer wide- ranging applications for food packaging (Zhuang et al., 2018). They have also been used as a semi-permeable barrier to reduce moisture loss and control gas exchange, thereby prolonging shelf-life and enhancing food quality (Leo et al., 2018). Tamarind kernel polysaccharide (TKP), a by-product of the tamarind industry, is a biodegradable polymer obtained from the seed endosperm of tamarind (*Tamarindus indica*, L.). TKP is composed of a (1→4)-β-D-glucan backbone substituted with side chains of α-D-xylopyranose and β-D-galactopyranosyl (1→2)-α-D-xylopyranose linked (1→6) to glucose residues (del Real, Wallander, Maciel, Cedillo, & Loza, 2015). TKP has been widely used as a stabilizing agent, thickener, emulsifier and encapsulant in the pharmaceutical and food industries (González-Martínez et al., 2017), due to its low cost, biocompatibility and non-toxicity (Pal & Pal, 2017). It has also been reported as a good film-forming material. TKP film exhibits poor moisture barrier properties but these can be improved by the addition of lipid to reduce hydrophilicity (Rodrigues et al., 2018).

Eggs are an inexpensive source of high-quality protein (Muñoz, Dominguez-Gasca, Jimenez-Lopez, & Rodriguez-Navarro, 2015). However, they have short shelf-life which limits marketability and results in significant economic losses. Egg deterioration is mainly the result of moisture and carbon dioxide loss through the shell. This causes quality changes in albumen, yolk and weight loss during storage (Suppakul, Jutakorn, & Bangchokedee, 2010). Research into polysaccharide-based coatings applied on the eggshell surface to preserve the internal quality of eggs had included sweet potato starch containing thyme essential oil (Eddin & Tahergorabi, 2019; Eddin, Ibrahim, & Tahergorabi, 2019), sodium alginate (Zhuang et al., 2018), chitosan (Leleu et al., 2011; Wardy, Martínez, Xu, No, & Prinyawiwatkul, 2014), chitosan combined with gamma irradiation (Liu et al., 2009; Yun et al., 2012), methyl cellulose and hydroxypropyl methyl cellulose (Suppakul, Jutakorn, & Bangchokedee, 2010).

Soybean oil coating is perceived as an alternative to mineral oil for extending the shelf-life of eggs due to its hydrophobicity, organic properties and low cost. Wardy, Torrico, No, Prinyawiwatkul and Saalia (2010) found that eggs coated with soybean oil or mineral oil showed significantly reduced weight loss and maintained yolk and albumen quality throughout the storage period. However, the long drying time of eggs coated with oil causes delays in marketing compared to other coatings (Wardy et al., 2011). To minimize marketing delay, chitosan-soybean oil emulsion (Wardy et al., 2011) and chitosan-mineral oil emulsion (Torrico et al., 2014) coatings were developed to provide an effective moisture and gas barrier to slow down egg degradation.

To the best of our knowledge, no study has focused on the application of TKP-SO emulsion coating to maintain the internal quality of fresh eggs. Therefore, here, TKP coatings were incorporated with varying concentrations of soybean oil, and the effects of these TKP-SO emulsion coatings on internal quality and shelf-life of eggs were evaluated.

2. Objectives

The objective of this work was to evaluate the effects of tamarind kernel polysaccharide (TKP)-soybean oil (SO) emulsion coating compare to SO on quality and shelf-life of fresh eggs during 35 d storage at 25 °C.

3. Materials and methods

3.1 Materials

Tamarind (Tamarindus indica) kernel powder was obtained from Freshy Thai Co., Ltd (Chachoengsao Province, Thailand). Soybean oil (SO) was purchased from Thai Vegetable Oil PCL. (Nakhon Pathom Province, Thailand). Tween® 80 (polyoxyethylene-20-sorbitan monooleate, Sigma-Aldrich, St Louis, MO, USA) was used as an emulsifier. Fresh eggs (AA grade) were purchased from Kasemchaifood Co., Ltd. (Nakhon Pathom Province, Thailand).

3.2 Preparation of coating materials

Tamarind kernel polysaccharide (TKP) solution was prepared from tamarind kernel powder according to the procedure described by González-Martínez et al. (2017) with some modifications. Briefly, tamarind kernel powder was dissolved in distilled water to obtain a 4% (w/v) solution and stirred on a hotplate using a magnetic stirrer (Laboratory & Medical Supplies, HTS-1003, Tokyo, Japan) at 85 °C for 20 min. The TKP solution was then filtered. Emulsions of TKP and SO (SO:TKP) at ratios of 10:90 and 30:70 were prepared by dispersing Tween® 80 (2% v/v) in TKP solution. SO was subsequently added and the mixture was homogenized for 3 min at low speed and then for another 6 min at high speed using an agitator (IKA, RW20, Germany) at 25 ± 2 °C.

3.3 Egg coating and storage condition

Grade AA 1-day old eggs were obtained from a local commercial egg producer (Kasemchaifood Co., Ltd., Thailand). The eggs were transported immediately under 25 ± 2 °C to the laboratory within 5 hours. The eggs were screened for defects and desirable weight range (70-75 g). Cleaned eggs were immersed in the coating materials (TKP, SO, SO:TKP at ratios of 10:90 and 30:70) for 1 min. The coated eggs were placed small end down on racks for drying at room temperature for 18 h. Non-coated eggs were used as the control group. Each egg was weighed using a balance (Mettler Toledo, ME204, Columbus, USA) to measure the initial weight in grams. Coated eggs were placed on egg racks and stored at 25 ± 2 °C, 65 ± 2% RH. Quality measurements were performed on five eggs per treatment every 7 d for 35 d of storage. All experiments were performed in triplicate.

3.4 Weight loss

The weight (W) of each egg was measured in grams. Weight loss of coated and non-coated eggs was calculated by subtracting the final weight from the initial weight and divided by the initial weight for each day of the analysis. Percentage weight loss was calculated by multiplying the weight loss by 100.

3.5 Haugh unit

A digital caliper (Mitutoyo Corporation, CD-6"ASX, Japan) was used to measure the albumen height (H, mm). The height was calculated as the mean of three measurements taken at different points of the albumen. The Haugh unit (HU) was calculated as 100 log (H – 1.7 W 0.37 + 7.57) (Haugh, 1937). Egg grade was based on the United States Standards for Quality of Individual Shell Eggs (USDA, 2000).

3.6 Albumen and yolk pH

The yolk was separated from the albumen and albumen and yolk pH were measured using a digital pH meter (Mettler-Toledo, Ohio, USA).

3.7 Yolk index

A digital caliper (Mitutoyo Corporation, CD-6"ASX, Japan) was used to measure the yolk height (mm) and yolk diameter (mm). Yolk index (YI) was calculated as yolk height (mm) per yolk diameter (mm) (Wardy et al., 2014).

3.8 Statistical analysis

Analysis of variance (ANOVA) and Duncan's new multiple range test were performed at a significance level of $p \leq 0.05$ using SPSS 10.0 statistical software.

4. Results and discussion

4.1 Haugh unit

The Haugh unit represents albumen quality as a function of albumen height and egg weight (Haugh, 1937). Results in Table 1 show that the Haugh unit of eggs in all treatments generally decreased with increasing storage time. Eggs were graded based on the Haugh unit (USDA, 2000) as AA (100 to 72), A (71 to 60), B (59 to 30) and C (below 29). Except for eggs coated with TKP, all coated eggs maintained an A-grade for 21 d of storage at 25 °C. Eggs coated with TKP maintained A-grade for 7 d, whereas non-coated eggs changed from grade AA to grade B within 7 d of storage. After 28 d, the control group and all coated eggs exhibited a B-grade at 25 °C. Concentration of SO did not result in a significant ($p > 0.05$) difference in Haugh units of eggs coated with TKP-SO emulsion. This implied that higher SO concentrations may not be advantageous in enhancing Haugh unit measurements during 35 d storage at the experimental conditions used in this study. Wardy et al. (2011) determined the quality of eggs coated with either SO or chitosan-soybean oil (CH:SO = 40:60 ratio) emulsion coating. They reported that the uncoated eggs changed in quality from grade AA to grade B after 7 d of storage. In comparison with our results, eggs coated with the SO and CH-SO at the ratio of 40:60 remained in grade A throughout 35 d of storage at 25 °C, whereas all coated eggs exhibited a B-grade after 42 d of storage. This could be implied that the concentration of soybean oil incorporated up to 60% v/v was more effective for maintaining the internal quality of fresh eggs during storage. Furthermore, the effectiveness of the coating materials for prolonging shelf-life of coated egg also depends on their water vapor, oxygen and carbon dioxide barrier properties which affect the permeation of moisture and carbon dioxide through egg shell during the storage (Eddin, Ibrahim, & Tahergorabi, 2019).

Changes in the quality of non-coated eggs and eggs coated with TKP, TKP-SO emulsion and SO during 35 d storage at 25 ± 2 °C are represented in Figure 1. The results in Figure 1 show that the liquefaction of the dense albumen increased for all treatments during storage time, but the reduction in dense albumen was more pronounced for non-coated eggs and eggs coated with TKP. The observation was consistent with the decrease of Haugh unit values for non-coated and coated eggs in all treatments. Albumen becomes less viscosity due to ovomucin proteolysis, cleavage of disulfide bridges or the interaction between α-ovomucin and β-ovomucin during storage (Pires et al., 2019). Our results indicated that the reduction of the albumen viscosity decreases the albumen height and consequently reduces Haugh unit values. Similarly, lower egg yolk quality in all treatment was observed with increased storage time. After 35 d of storage, non-coated eggs and eggs coated with TKP showed an obviously increase in yolk diameter compared to eggs coated with TKP-SO emulsions and SO. An increase in yolk diameter is mainly due to the diffusion of water from the albumen to the yolk during storage (Geveke, Gurtler, Jones, & Bigley, 2016). These findings implied that TKP-SO emulsion and SO coatings reduced the water vapor and carbon dioxide transfer rate from the albumen through the eggshell during storage period. The coatings inhibit albumen liquefaction and water uptake by the yolk resulting in a reduction of yolk deterioration (Caner & Yüceer, 2015).

Table 1 Changes in Haugh unit[1] and egg grade[2] during 35 d storage at 25 ± 2 °C

Treatment[3]	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35
NC	79.53^{a,A} (8.68) AA	50.52^{b,B} (8.41) B	44.26^{c,B} (6.35) B	46.95^{b,B} (5.44) B	50.03^{a,B} (3.18) B	46.50^{b,B} (5.49) B
TKP	77.18^{a,A} (9.83) AA	64.78^{ab,B} (8.63) A	57.07^{b,BC} (2.89) B	55.92^{ab,BC} (4.37) B	54.83^{a,BC} (4.78) B	51.37^{ab,C} (4.47) B
TKP-SO10	89.82^{a,A} (4.14) AA	69.88^{a,B} (8.81) A	60.64^{b,BC} (3.89) A	62.49^{a,BC} (6.09) A	57.28^{a,C} (2.64) B	59.34^{a,BC} (1.87) B
TKP-SO30	87.23^{a,A} (5.60) AA	69.52^{a,B} (4.40) A	69.26^{a,B} (1.74) A	65.71^{a,BC} (5.98) A	55.77^{a,D} (4.06) B	58.43^{a,CD} (1.80) B
SO	79.38^{a,A} (4.51) AA	71.64^{a,AB} (8.83) A	70.40^{a,AB} (6.46) A	61.21^{a,BC} (5.10) A	58.05^{a,BC} (8.47) B	56.48^{ab,C} (5.94) B

[1]Values are mean with standard deviation in brackets (n = 15)
[2]Egg grades: AA (HU > 72), A (HU = 71-60), B (HU = 59-30), C (HU < 29) (Haugh, 1937; USDA, 2000)
[3]NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO: TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil
$^{a, b, c}$ means with different superscripts within a column indicate significant differences ($p \leq 0.05$).
$^{A, B, C, D}$ means with different superscripts within a row indicate significant differences ($p \leq 0.05$).

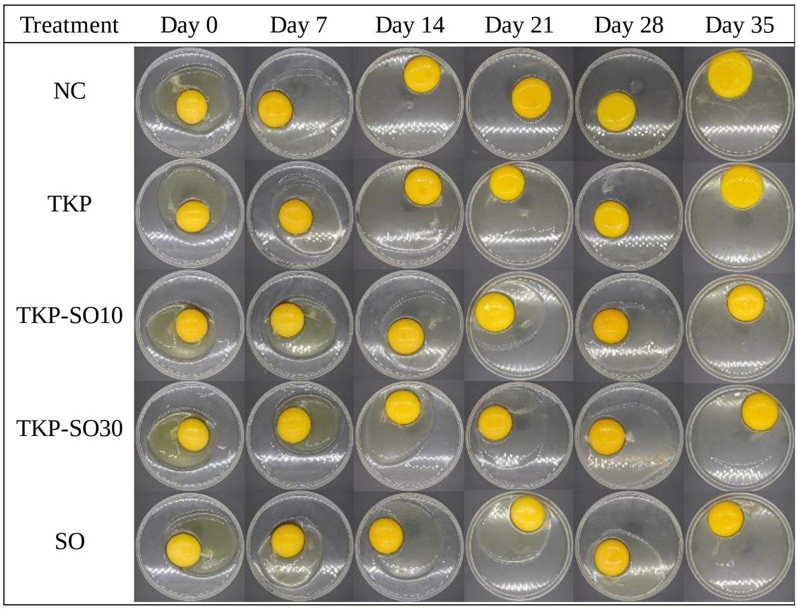

Figure 1 Changes in the quality of fresh eggs during 35 d storage at 25 ± 2 °C. NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil

4.2 Weight loss

Egg weight loss in all treatments increased with longer storage time (Figure 2). The effect of coating materials on reducing weight loss was significantly ($p \leq 0.05$) different after 7 d of storage at 25 °C. The results in Figure 2 show that weight loss during 7 and 35 d of storage at 25 °C of eggs coated with TKP-SO10 (0.35-2.29%) and TKP-SO30 (0.47-2.38%) was lower than for non-coated eggs (0.96-5.67%) and eggs coated with

TKP only (0.84-5.13%) throughout the storage period. This result was attributed to the number of hydroxyl groups of tamarind kernel polysaccharide (Figure 3) that are easily accessible by water molecules as higher for TKP coating compared to TKP-SO emulsions (Kochumalayil, Sehaqui, Zhou, & Berglund, 2010). No significant (p > 0.05) difference was observed in weight loss between eggs coated with TKP-SO emulsion at 10:90 and 30:70 ratios. The SO-coated eggs showed the lowest weight loss at 0.11-0.54% but exhibited the longest drying time (data not shown) compared to other treatments. Results indicated that TKP-SO emulsion coatings (SO:TKP = 10:90 and 30:70) exhibited sufficient hydrophobicity required to delay moisture loss of the eggs during storage. Wardy et al. (2011) reported that SO significantly reduced moisture loss compared to chitosan-soybean oil emulsion (CH:SO = 40:60) coating for eggs stored at 25 °C, while Rodrigues et al. (2018) revealed that water vapor permeability of the films decreased with incorporation of sesame seed oil from tamarind kernel xyloglucan. This was attributed to the tortuous pathways that retarded diffusion of water molecules through the polymer matrix.

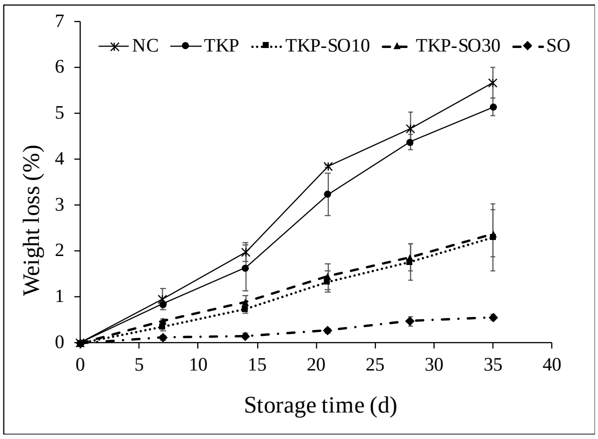

Figure 2 Weight loss (%) of coated and non-coated eggs during 35 d of storage at 25 ± 2 °C. NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil

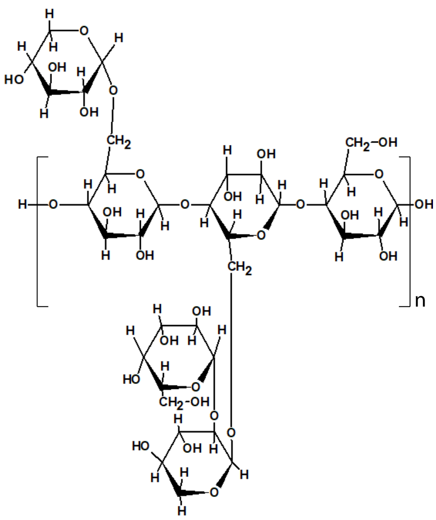

Figure 3 The chemical structure of tamarind kernel polysaccharide

4.3 Albumen and yolk pH

Albumen pH of non-coated eggs and eggs coated with TKP increased, whereas a decrease was found in eggs coated with TKP-SO emulsion and SO (Table 2). Increase in albumen pH caused reduction in egg quality due to loss of carbon dioxide (Wardy et al., 2014). Results indicated that albumen pH of non-coated eggs from 7 to 21 d was significantly ($p \leq 0.05$) higher than eggs coated with TKP. This was attributed to the hydrophilic properties of TKP which were highly effective in preventing loss of carbon dioxide through pores in the eggshell (Rodrigues et al., 2018; Wardy et al., 2011). No significant ($p > 0.05$) differences were recorded in the albumen pH of eggs coated with TKP-SO emulsions and SO, while eggs coated with TKP-SO emulsions gave higher quality compared to those coated with TKP. Yolk pH slightly increased with storage time (Table 3). Overall, the effect of SO concentration on the pH of egg yolk was not significantly ($p > 0.05$) different throughout 35 d storage at 25 °C.

Table 2 Albumen pH[1] of coated and non-coated eggs during 35 d of storage at 25 ± 2 °C

Treatment[2]	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35
NC	$8.93^{ns,C}$ (0.08)	$9.34^{a,B}$ (0.04)	$9.33^{a,B}$ (0.08)	$9.51^{a,A}$ (0.08)	$9.44^{a,AB}$ (0.04)	$9.42^{a,AB}$ (0.04)
TKP	$8.82^{ns,NS}$ (0.06)	$8.86^{b,NS}$ (0.12)	$8.73^{ab,NS}$ (0.72)	$9.91^{b,NS}$ (0.22)	$9.17^{a,NS}$ (0.40)	$9.14^{ab,NS}$ (0.41)
TKP-SO10	$8.99^{ns,A}$ (0.05)	$8.55^{c,AB}$ (0.06)	$8.47^{b,AB}$ (0.09)	$8.35^{c,B}$ (0.17)	$8.02^{b,B}$ (0.32)	$8.09^{c,B}$ (0.59)
TKP-SO30	$8.89^{ns,A}$ (0.17)	$8.57^{c,AB}$ (0.04)	$8.14^{b,BC}$ (0.25)	$8.39^{c,ABC}$ (0.03)	$8.15^{b,BC}$ (0.29)	$7.80^{c,C}$ (0.73)
SO	$8.95^{ns,A}$ (0.09)	$8.51^{c,B}$ (0.04)	$8.41^{b,B}$ (0.01)	$8.52^{c,B}$ (0.06)	$8.45^{b,B}$ (0.14)	$8.49^{bc,B}$ (0.12)

[1]Values are mean with standard deviation in brackets (n = 15)
[2]NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil
[a, b, c]Means with different superscripts within a column indicate significant differences ($p \leq 0.05$).
[A, B, C, D]Means with different superscripts within a row indicate significant differences ($p \leq 0.05$).

Table 3 Yolk pH[1] of coated and non-coated eggs during 35 d of storage at 25 ± 2 °C

Treatment[2]	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35
NC	$6.19^{ns,NS}$ (0.30)	$6.31^{ns,NS}$ (0.18)	$6.37^{ns,NS}$ (0.33)	$6.23^{b,NS}$ (0.05)	$6.35^{ns,NS}$ (0.04)	$6.46^{a,NS}$ (0.05)
TKP	$6.00^{ns,B}$ (0.14)	$6.22^{ns,AB}$ (0.11)	$6.24^{ns,AB}$ (0.28)	$6.20^{b,AB}$ (0.16)	$6.33^{ns,A}$ (0.10)	$6.38^{ab,A}$ (0.09)
TKP-SO10	$6.06^{ns,NS}$ (0.20)	$6.18^{ns,NS}$ (0.06)	$6.28^{ns,NS}$ (0.29)	$6.16^{b,NS}$ (0.03)	$6.28^{ns,NS}$ (0.16)	$6.24^{bc,NS}$ (0.11)
TKP-SO30	$6.14^{ns,NS}$ (0.22)	$6.16^{ns,NS}$ (0.13)	$6.22^{ns,NS}$ (0.24)	$6.23^{b,NS}$ (0.05)	$6.21^{ns,NS}$ (0.15)	$6.15^{c,NS}$ (0.10)
SO	$6.13^{ns,NS}$ (0.19)	$6.27^{ns,NS}$ (0.03)	$6.16^{ns,NS}$ (0.35)	$6.38^{a,NS}$ (0.29)	$6.22^{ns,NS}$ (0.12)	$6.24^{bc,NS}$ (0.03)

[1]Values are mean with standard deviation in brackets (n = 15)
[2]NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil
[a, b, c]Means with different superscripts within a column indicate significant differences ($p \leq 0.05$).
[A, B, C, D]Means with different superscripts within a row indicate significant differences ($p \leq 0.05$).

4.4 Yolk index

Yolk index (YI) of eggs in all treatments significantly ($p \leq 0.05$) decreased with storage time (Figure 4). The YI value of eggs coated with TKP was significantly ($p \leq 0.05$) lower than eggs coated with TKP-SO emulsions and SO throughout the storage period. The lowest YI value was found in non-coated eggs. No significant ($p > 0.05$) difference was recorded in YI between SO and TKP-SO emulsion-coated eggs. Wardy et al. (2011) reported no significant ($p > 0.05$) difference in YI values of eggs coated with SO and chitosan-soybean oil emulsion after 7 d storage at 25 °C. Reduction of YI value occurred due to the migration of water molecules from the albumen through the yolk membrane, resulting in flattening of the yolk during storage (Torrico et al., 2011).

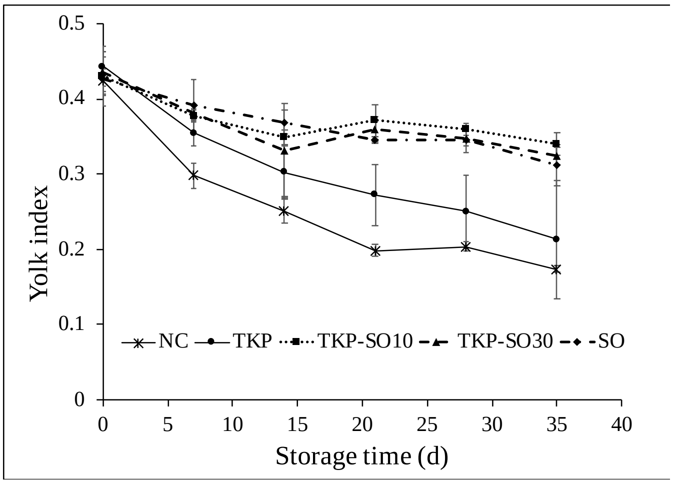

Figure 4 Yolk index of coated and non-coated eggs during 35 d of storage at 25 ± 2 °C. NC, no coating; TKP, eggs coated with tamarind kernel polysaccharide; TKP-SO10, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 10:90; TKP-SO30, eggs coated with an emulsion of tamarind kernel polysaccharide and soybean oil at the ratio of SO:TKP 30:70; SO, eggs coated with soybean oil

5. Conclusion

Coating with TKP-SO emulsions and SO preserved the internal quality of eggs during 35 d storage at 25 °C significantly ($p \leq 0.05$) greater than eggs coated with TKP and non-coated eggs. No significant ($p > 0.05$) difference in egg grades was found between SO and TKP-SO emulsion-coated eggs throughout the storage period. No effect of different SO concentrations incorporated in the emulsion coating was observed for egg quality in terms of Haugh unit, weight loss, albumen pH, yolk pH and yolk index. Eggs coated with TKP-SO emulsions showed higher weight loss but exhibited lower drying time compared to SO coated-eggs. In conclusion, the TKP-SO emulsion coatings are promising coating materials for enhancing the shelf-life of fresh eggs and potentially other food products. The formulation and the technique used to prepare the TKP-SO emulsion coatings to better preserve the quality and shelf-life of fresh eggs compared to other commercial biodegradable coatings should be investigated in future research.

6. Acknowledgements

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