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Effects of Chitosan-Stearin on Quality of Chicken Egg Storage at Room Temperature

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ABSTRACT

Consumption of chicken eggs has perishable properties, the quality of eggs declines faster and the shelf life of eggs is considerably short at room temperature compared to cold temperatures. The present study aimed to evaluate the application of chitosan-stearin as a coating on the quality of chicken egg storage at room temperature. The present study used a Completely Randomized Design (CRD) 4 x 5 factorial pattern with three replications. Each replicate consisted of six fresh chicken eggs, resulting in 360 eggs. The groups included Without Coating (FD0), Virgin Coconut Oil (FD1), 1.5% Chitosan + 1% Stearin (FD2), and 3% Chitosan + 1% Stearin (FD3). The second effective variable in grouping was storage time 0 Days (ST0), 14 Days (ST14), 28 Days (ST28), 42 Days (ST42), and 56 Days (ST56). The current results indicated that the storage time and the formula dosage had a notable effect on haugh unit, yolk index, and albumen index, but no significant effect on the pH of the albumen. Formula dosage had no significant effect, but storage time had a significant effect on yolk pH and color, and weight loss. There was an interaction between formula dosage and storage time on haugh unit, albumen index, and yolk index, but there was no interaction on albumen pH, weight loss, yolk pH, and yolk color. The Chitosan-Stearin coating can maintain the quality of chicken eggs during storage for up to 56 days. The use of 3% Chitosan + 1% Stearin as a coating formula indicated the best results in maintaining the quality of chicken eggs during storage time at room temperature.

Keywords: Chicken egg, Chitosan, Coating, Room temperature, Stearin

INTRODUCTION

Purebred chicken eggs are widespread due to their high quality, easy availability, and relatively affordable prices (Abbas et al., 2024). Purebred chicken eggs are composed of 10% shell (eggshell/shell), 60% albumen, and 30% yolk (Almeida et al., 2021). The nutritional content of purebred chicken eggs is 12.9 g protein, 11.2 g fat, and 0.9 g carbohydrates per grain (BALITBANGTAN, 2021). Purebred chicken eggs have perishable properties, egg quality decreases faster at room temperature than at cold temperatures and the shelf life of the egg is typically only 10–14 days at room temperature before spoilage occurs (BSN, 2023). In addition, during the storage (room temperature) process, eggs undergo changes in their quality, namely increasing egg weight loss, albumen pH, and yolk pH and decreasing haugh unit values, albumen index, and yolk index (Sariyel et al., 2022).

In general, people handle chicken eggs using a refrigerator, although not everyone possesses this appliance. In addition, the Indonesian government program "free nutritious meal" utilizes eggs as a protein source (Desiani and Syafiq, 2025). Distribution to Eastern Indonesia requires careful consideration of the supply chain to ensure a consistent supply of quality eggs. An alternative for extending egg shelf life involves coating the eggshell to seal the pores that can control the transfer of moisture such as oxygen (O_2) and carbon dioxide (CO_2) (Rachtanapun et al., 2022). Different coating materials

have been studied, but the combination of Chitosan-Stearin has not been used (Fahmi et al., 2023).

Chitosan can be isolated from the shell of crab (*Portunus pelagicus*) which is one of the crustaceans. Crab shells have a lower mineral content than crab and shrimp shells at 22.93% and have a chitosan content of 20–30% (Nurhayati et al., 2022). Chitosan also has the properties and characteristics of biodegradable, antimicrobial, non-toxic, and a barrier to the escape of water vapor and gas in a product due to the polysaccharides of the strong chitosan layer (Picos-Corrales et al., 2023). Chitosan is the result of the deacetylation of chitin obtained by extraction (Nasution et al., 2020). Chitosan extraction is carried out at the stages of demineralization, deproteination, depigmentation, and deacetylation and chitosan can dissolve in acetic acid at a concentration of 1-2% (Mirwandhono et al., 2022). Due to the different sources and concentrations of materials employed in the extraction process, as well as the fact that chitosan is highly versatile, chitosan extraction can yield a diversity (Mirwandhono et al., 2024).

Stearin is a co-product of palm oil production, constitutes 20–30% of the oil, and has limited use as a coating material. In producing stearin through the stages of refining, bleaching, deodorizing, and cooling (Widowati et al., 2024). Stearin contains palmitic acid which acts as an antimicrobial (Sulaiman et al., 2022). Stearin is used as a coating that has a function to improve water vapor permeability, and flexibility, can cause a gloss effect, and maintain the structure and shape of the product during storage (Agusta et al., 2022).

Different studies on the manufacture and use of crustacean-based chitosan have been conducted from shrimp shells and crab shell waste in different applications, one of which was the coating effect (Ngasotter et al., 2023). However, no one has used a combination of chitosan from crab shell waste (*Portunus pelagicus*) and palm stearin applied to the fresh consumption of chicken eggs. Thus, the present study aimed to evaluate the effects of Chitosan-Stearin as a coating factor on the quality of chicken egg storage at room temperature.

MATERIALS AND METHODS

Materials

Materials used in the present study were crab shell chitin (*Portunus pelagicus*) degree of deacetylation (DD) 73.14% and palm stearin from the Palm Oil Research Center Bogor Unit (Indonesia), freshly harvested chicken eggs at 50–60 weeks of age (after peak production) with the Lohmann Brown strain and sorted with a weight of 60–65 g from Perseroan Terbatas (PT) Global Buwana Farm, Indonesia. Tools were haugh digital micrometer (PT. DIFOTEK, Indonesia), Roche yolk color fan (PT. DIFOTEK, Indonesia), pH meter (PT. DIFOTEK, Indonesia), hygrometer (PT. DIFOTEK, Indonesia), caliper, digital scale, glass table, filter paper, plastic, knife, basin, hotplate, stirrer, rubber binder, brush, egg yolk separator, and mica tray.

Method

Egg quality data were analyzed using a factorial completely randomized design (CRD) with two factors and three replications were used in the present study. Each replicate consisted of six fresh eggs, resulting in 360 eggs. The grouping included (Fahmi et al., 2023) Without Coating (FD0), Virgin Coconut Oil (FD1), 1.5% Chitosan + 1% Stearin (FD2), and 3% Chitosan + 1% Stearin (FD3). The second effective factor in grouping was the storage time which included 0 Days (ST0), 14 Days (ST14), 28 Days (ST28), 42 Days (ST42), and 56 Days (ST56).

Deacetylation of chitin

To produce the DD findings applied to the coating of chicken eggs, 50% NaOH was used to deacetylate chitin into chitosan (Yunilas et al., 2023). 50% NaOH was added to crab shell (*Portunus pelagicus*) chitin (DD 73.14%) from the Palm Oil Research Center Bogor Unit, Indonesia in a 1:10 (w/v) ratio, mixed, and heated for 6 hours at 100 ^{o}C. filtered, cleaned to a pH of neutral, and then dried for 24 hours at 60 ^{o}C in an oven. Chitosan was the name given to the resultant particles.

Coating formula

The preparation formula of the chitosan as a coating from crab shells was carried out using 2% acetic acid at 40 ^{o}C while palm stearin was melted at 60 ^{o}C (Fahmi et al., 2023). Then the chitosan solution of the crab shell was mixed with the palm stearin solution and 2% tween 80 (Sigma-Aldrich, France) was added according to the variation of the ratio (Hanani et al., 2012). Then the solution was stirred for four minutes with a magnetic stirrer.

Coating application

Fresh-consumption chicken eggs were cleaned by dry cleaning using a sponge. The coating on eggs was done by dipping technique (Revanda and Puspitarini, 2024),

namely by dipping the egg sample into the coating solution for 15 minutes, then lifted and placed on a mica tray and aerated until the coating solution stuck to fresh chicken eggs, then stored at an average room temperature of 28 ^{o}C and an average humidity of 56%. Each chicken egg required one mL of coating formula solution that has been designed by the authors.

Variables

The variables including weight loss (Hintono, 1997), haugh unit (BSN, 2023), albumen index (BSN, 2023), yolk index (BSN, 2023), albumen pH (Eke et al., 2013), yolk pH (Eke et al., 2013), and yolk color (Thohari et al., 2022) were measured.

Data analysis

Data analysis was carried out using SAS software and data were analyzed using variance analysis (Mattjik and Sumertajaya, 2013). If the obtained results were confirmed to be real or highly credible, they were further analyzed using the Duncan Multiple Range Test (DMRT) with a significant level ($p < 0.05$).

RESULTS

Chitosan characteristics

Properties of chitosan, such as the color, texture, odor, solubility, and level of deacetylation were presented in Table 1. According to the current investigation, the chitosan derived from crab shells was odorless, powder-shaped, white-light brown, and soluble in 2% acetic acid.

Table 1. Characterization of chitosan obtained from crab shells

Parameters	Results
Odor	Odorless
Color	White-light brown
Texture	Powder
Solubility in 2% acetic acid	Soluble
Degree of deacetylation (%)	79.52

Quality of coated chicken egg

Results of this research with the parameters of weight loss, haugh unit, albumen index, yolk index, albumen pH, yolk pH, and yolk color were illustrated in Table 2. Weight loss of chicken eggs in the present study ranged from 0.00 to 6.20%. The percentage of weight loss in FD1, FD2, and FD3 increased compared to FD0. The results indicated that the formula dosage had no significant effect ($p > 0.05$) while the storage time had a significant effect ($p < 0.05$) on weight loss and there was no interaction between the formula dose and storage time ($p > 0.05$).

Haugh unit of chicken eggs in the present study ranged from 13.34 to 91.61%. The percentage of haugh units of eggs in FD1, FD2, and FD3 decreased compared to FD0. The results indicated that the formula dosage and storage time had a very significant effect ($p < 0.05$) on the haugh unit of chicken eggs and there was an interaction between formula dosage and storage time ($p < 0.05$).

The albumin index of chicken eggs in the present study ranged from 0.02 to 0.10%. The percentage of albumen index in FD1, FD2, and FD3 decreased compared to FD0. The results of the variance analysis indicated that the formula dosage and storage time had a significant effect on the albumen index of chicken eggs ($p < 0.05$) and there was an interaction between formula dosage and storage time ($p < 0.05$).

The yolk index of chicken eggs in the study ranged from 0.25 to 0.40%. The percentage of yolk index in FD1, FD2, and FD3 decreased compared to FD0. Results of the variance analysis indicated that the formula dosage and storage time had a significant effect ($p < 0.05$) on the yolk index of chicken eggs and there was an interaction between the formula dosage and storage time ($p < 0.05$).

The albumen pH of chicken eggs ranged from 7.97 to 8.17. The percentage of albumen pH in the present study in FD1, FD2, and FD3 did not experience a certain increase or decrease but seemed to fluctuate compared to FD0. Results of the analysis of variance showed that the formula dosage and storage time had no significant effect ($p > 0.05$) on the pH of chicken eggs albumen and there was no interaction between the dose and length of storage ($p > 0.05$). The yolk pH of chicken eggs in the current study ranged from 6.25 to 7.11. The percentage of yolk pH in FD1, FD2, and FD3 fluctuated compared to FD0. The results showed that the formula dosage had no significant effect ($p > 0.05$) while the storage time had a very significant effect ($p < 0.05$) on the pH of egg yolks and there was no interaction between the formula dosage and storage time ($p > 0.05$). The yolk color of chicken eggs in the current study ranged from 6.11 to 7.89. The percentage of yolk color in FD1, FD2, and FD3 fluctuated compared to FD0. The results showed that the formula dosage had no significant effect ($p > 0.05$) while the storage time had a significant effect ($p < 0.05$) on the yolk color of eggs and there was no interaction between the formula dosage and storage time ($p > 0.05$). Yolk color in the study showed that egg handling with coating can prevent high yolk color loss (Figure 1).

Table 2. Quality of coated chicken egg storage at 28 ^{o}C and an average humidity of 56%

Items	Weight loss (%)	Haugh unit (%)	Albumen index (%)	Yolk index (%)	Albumen pH	Yolk pH	Yolk color
Storage Time (ST)							
ST0	0.00^{A}	91.58	0.09	0.40	8.04^{NS}	6.27^{A}	7.78^{E}
ST14	2.05^{B}	70.14	0.07	0.38	8.08^{NS}	6.85^{B}	7.44^{D}
ST28	3.55^{C}	60.94	0.06	0.34	8.10^{NS}	6.97^{CD}	7.27^{C}
ST42	4.20^{CD}	55.13	0.05	0.32	8.12^{NS}	7.04^{CD}	6.72^{B}
ST56	5.11^{DE}	47.44	0.03	0.30	8.13^{NS}	7.08^{DE}	6.27^{A}
P-value	8.40**	1.46**	3.81**	1.55**	0.62^{NS}	1.06**	4.23**
Formula Dosage (FD)							
FD0	3.49^{NS}	42.84	0.05	0.32	8.07^{NS}	6.81^{NS}	6.97^{NS}
FD1	2.88^{NS}	73.93	0.06	0.35	8.10^{NS}	6.87^{NS}	7.17^{NS}
FD2	3.07^{NS}	69.18	0.06	0.34	8.08^{NS}	6.82^{NS}	7.04^{NS}
FD3	2.49^{NS}	74.24	0.07	0.37	8.12^{NS}	6.87^{NS}	7.20^{NS}
P-value	0.14^{NS}	1.82**	1.41**	1.01**	0.82^{NS}	0.34^{NS}	0.09^{NS}
Interaction (ST x FD)							
ST0FD0	0.00^{NS}	91.58^{A}	0.10^{A}	0.40^{A}	7.97^{NS}	6.25^{NS}	7.89^{NS}
ST0FD1	0.00^{NS}	91.61^{CD}	0.09^{C}	0.39^{C}	8.07^{NS}	6.26^{NS}	7.78^{NS}
ST0FD2	0.00^{NS}	91.54^{B}	0.10^{B}	0.40^{B}	8.04^{NS}	6.29^{NS}	7.67^{NS}
ST0FD3	0.00^{NS}	91.60^{CD}	0.10^{D}	0.40^{D}	8.08^{NS}	6.28^{NS}	7.78^{NS}
ST14FD0	2.34^{NS}	49.51^{A}	0.07^{A}	0.36^{A}	8.05^{NS}	6.83^{NS}	7.22^{NS}
ST14FD1	2.05^{NS}	79.52^{CD}	0.07^{C}	0.38^{C}	8.08^{NS}	6.88^{NS}	7.55^{NS}
ST14FD2	2.11^{NS}	71.80^{B}	0.07^{B}	0.38^{B}	8.08^{NS}	6.83^{NS}	7.44^{NS}
ST14FD3	1.69^{NS}	79.73^{CD}	0.08^{D}	0.39^{D}	8.10^{NS}	6.88^{NS}	7.55^{NS}
ST28FD0	4.10^{NS}	37.09^{A}	0.04^{A}	0.32^{A}	8.11^{NS}	6.91^{NS}	7.11^{NS}
ST28FD1	3.45^{NS}	70.35^{CD}	0.06^{C}	0.35^{C}	8.11^{NS}	7.06^{NS}	7.44^{NS}
ST28FD2	3.62^{NS}	65.86^{B}	0.06^{B}	0.33^{B}	8.08^{NS}	6.89^{NS}	7.22^{NS}
ST28FD3	3.03^{NS}	70.45^{CD}	0.07^{D}	0.37^{D}	8.11^{NS}	7.02^{NS}	7.33^{NS}
ST42FD0	4.80^{NS}	22.67^{A}	0.03^{A}	0.29^{A}	8.10^{NS}	7.01^{NS}	6.55^{NS}
ST42FD1	4.10^{NS}	67.95^{CD}	0.06^{C}	0.33^{C}	8.13^{NS}	7.06^{NS}	6.78^{NS}
ST42FD2	4.14^{NS}	61.76^{B}	0.04^{B}	0.30^{B}	8.10^{NS}	7.02^{NS}	6.66^{NS}
ST42FD3	3.77^{NS}	68.17^{CD}	0.06^{D}	0.36^{D}	8.14^{NS}	7.06^{NS}	6.88^{NS}
ST56FD0	6.20^{NS}	13.34^{A}	0.02^{A}	0.25^{A}	8.12^{NS}	7.05^{NS}	6.11^{NS}
ST56FD1	4.81^{NS}	60.22^{CD}	0.05^{C}	0.33^{C}	8.13^{NS}	7.11^{NS}	6.33^{NS}
ST56FD2	5.47^{NS}	54.93^{B}	0.03^{B}	0.30^{B}	8.10^{NS}	7.07^{NS}	6.22^{NS}
ST56FD3	3.97^{NS}	61.27^{CD}	0.05^{D}	0.34^{D}	8.17^{NS}	7.10^{NS}	6.44^{NS}
P-value	0.98^{NS}	1.72**	4.15**	2.49**	0.99^{NS}	0.99^{NS}	0.96^{NS}

$^{A-E}$ and ** Means values in a column with different superscript letters indicate a significant difference ($p < 0.01$). ^{NS} Means value in a column with similar superscript letters indicates a non-significant difference ($p > 0.05$).

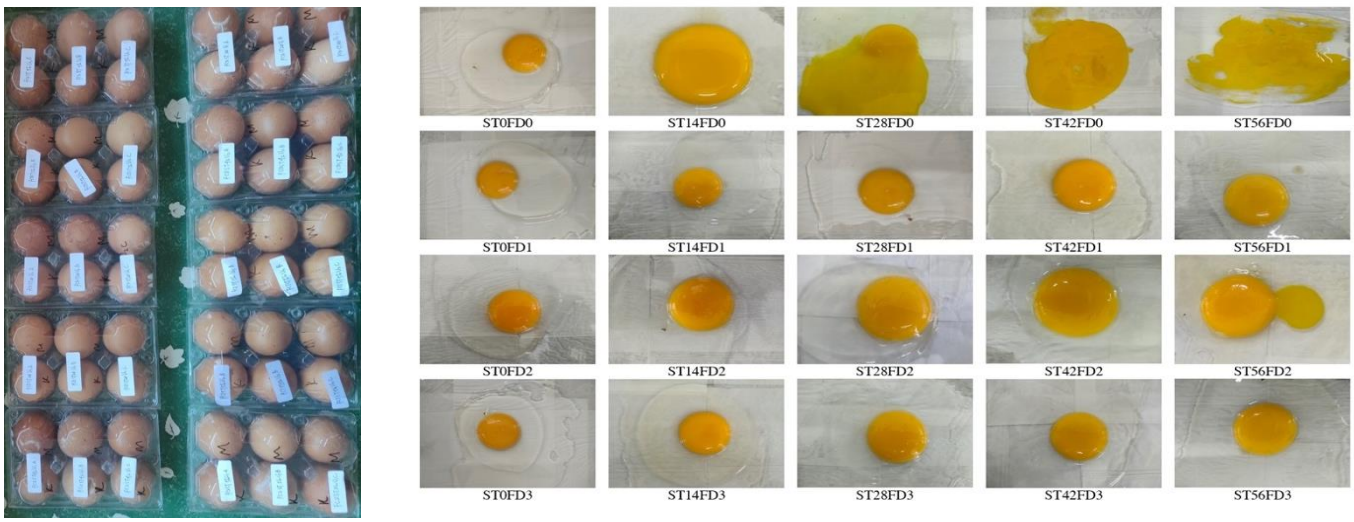

Figure 1. Chicken egg yolk shape during storage without coating (FD0), virgin coconut oil (FD1), 1.5% Chitosan + 1% Stearin (FD2), And 3% Chitosan + 1% Stearin (FD3). 0 days (ST0), 14 days (ST14), 28 days (ST28), 42 days (ST42), and 56 days (ST56)

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DISCUSSION

According to Alimi et al. (2023), the amount of chitosan produced depends significantly on the chitin source and how well the deacetylation step goes. Furthermore, by determining the acetyl group that was removed from the amide, the degree of deacetylation (DD) described the effectiveness of the deacetylation process of chitin into chitosan. Due to the extraction method, the resulting DD of this study was 79.52% (Table 1). Kahar et al. (2022), studied to obtain a DD of 79.35. According to Narudin et al. (2022), the extraction procedure or method resulted in both high and low DD.

In the present study from 0 to 56 days, samples without coating (FD0) experienced a high weight loss of 6.20%. Samples coated with virgin coconut oil (FD1) showed a weight loss of 4.81%. Samples coated with chitosan 1.5% + 1% stearin (FD2) had a weight loss of 5.47%, and samples coated with chitosan 3% + 1% stearin (FD3) experienced a weight loss of 3.97. In another current study conducted by Revanda and Puspitarini (2024), using virgin coconut oil for 45 days resulted in lower weight loss compared to the present study for 42 days. Virgin coconut oil-coated eggs for up to 42 days resulted in a weight loss of 4.10%, FD2 resulted in a weight loss of 4.14%, and FD3 resulted in a weight loss of 3.77%. Revanda and Puspitarini (2024), indicated that using virgin coconut oil with a storage period of 45 days resulted in a weight loss of 1.77%. According to Sheng et al. (2020) using chitosan with different origins, dosage, and DD for 42 days resulted in higher weight loss when compared to the present study for 42 days. Sheng et al. (2020), conducted that using crab-origin chitosan DD 90% at a dose of 2% + slightly acidic electrolyzed water and storage time for 42 days resulted in a weight loss of 5.35%.

Weight loss of eggs in the current study illustrated that the handling of eggs carried out by coating can prevent the occurrence of water vapor and coating treatment using chitosan, particularly FD2 and FD3, can prevent the transfer of water and gas to prevent the evaporation process which causes the weight loss of eggs to avoid experiencing a high decrease in eggs during storage. Because the high evaporation process happens because of the difference in water pressure inside and outside so that water vapor can come out, the low weight loss of eggs in the current investigation was caused by the low water pressure within and outside. In addition, eggs without coating experience high water pressure compared to eggs with coating. According to Rostamabadi et al. (2024), coating applications can prevent the occurrence of water vapor therefore preserving the high quality of the food products that have been coated. Aranaz et al. (2021) stated that the use of chitosan as a coating on a product such as food could act as a protective outer surface so, it would prevent the evaporation process. Luo et al. (2020) reported that during the storage of eggs, the internal water pressure exceeds the external pressure resulting in the water vapor release.

In the present study from 0 to 56 days, FD0 experienced a high decrease in haugh units of 13.34% compared to FD1 of 60.22%, FD2 of 54.93%, and FD3 of 61.27%. Sugiyono et al. (2022) studied virgin coconut oil for 42 days, resulting in a lower haugh unit of eggs than the present study. The FD1 up to 42 days resulted in haugh unit of 67.95%, FD2 up to 28 days resulted in haugh unit of 65.86%, and FD3 up to 28 days resulted in haugh unit of 70.45%. Sugiyono et al. (2022), conducted that using virgin coconut oil with a storage period of 42 days resulting in a haugh unit of 36.57%. According to a study by Zirabi et al. (2024), chitosan with different origins, dosage, and DD for 28 days resulted in a comparable egg haugh unit when compared to the present study for 28 days. Zirabi et al. (2024), indicated that using polyvinyl alcohol 5% + chitosan (DD 85%) with the concentrated use of 2% + montmorillonite 4% + garlic extract 4% with storage for 28 days resulted in haugh units of 70.00%.

As demonstrated in FD2 and FD3 treatments, handling eggs with coating can avoid a significant drop in haugh units of eggs, according to the current findings. Additionally, there was a correlation between the haugh unit and albumen height and weight. The haugh unit value increased with the albumen value. Conversely, the haugh unit value decreased as the albumen value decreased. In addition, small egg haugh units occur due to a change in the increase of water to the yolk. According to Gogo et al. (2021), eggs cannot have high quality if longer storage is carried out because eggs are easily damaged and the haugh unit of eggs can decrease with the length of storage. Ningtiyas et al. (2024), stated that the egg's haugh unit consistently correlated with egg weight and albumen height. The haugh unit value of eggs was influenced by the height of the albumen, with higher albumen values resulting in higher haugh unit value. Jaelani et al. (2021) reported that the haugh unit value of eggs can decrease during the storage period due to an increase in water to the yolk, and the length of egg storage carried out without coating can provide an opportunity to increase water to the yolk.

In the present study from 0 days to 56 days FD0 experienced a high decrease in albumen index of 0.02% compared to FD1 of 0.05%, FD2 of 0.03%, and FD3 of 0.05%. Another current study using virgin coconut oil for 21 days resulted in a higher albumen index compared to the present study for 28 days. The FD1 for up to 28 days resulted in an albumen index of 0.06%, FD2 for up to 28 days resulted in an albumen index of 0.06%, and FD3 for up to 28 days resulted in an albumen index of 0.07%. Irmawaty et al. (2022), conducted research using virgin coconut oil with a storage period of 21 days resulting in an albumen index of 0.07%. Likewise, the findings of Sapitri et al. (2020), chitosan with different origins, dosage, and DD for 28 days resulted in a lower albumen index when compared to the present study for 28 days. Sapitri et al. (2020) found that using sago starch + 2% chitosan with storage for 28 days resulted in an albumen index of 0.04%.

The albumen index in the present study indicated that preserving eggs with coating can prevent a high decrease in albumen index as shown in the FD2 and FD3 treatments. As the storage duration of eggs increased, the albumen index value decreased. During storage, egg white is the part that was quickly damaged due to the release of water vapor from the ovomucin nets which functioned as a structure builder in albumen. In addition, the water content in albumen was high, therefore the damage in albumen occurred faster. Uncoated albumen during storage was more susceptible to damage compared to coated albumen. By observing the dilution of the albumen, as the albumen became more diluted, the albumin index value decreased. According to Adriaensen et al. (2022), the albumen index decreased with the length of storage, so the albumen index encountered a small value. Jalili-Firoozinezhad et al. (2020) stated that the low or high albumen index value was caused by the evaporation of water from the ovomucin mesh, and albumen is a vitally important indicator because it is easily damaged, so it needs to be considered during storage. Amezua-Arranz et al. (2024) reported that during egg storage, attention must be paid to the quality of the albumen because the water content in the albumen is more than in other parts (yolk) and the albumen that seems to be damaged can be observed from the watery albumen (albumen that has a high-water content).

In the present study from 0 days to 56 days FD0 experienced a high yolk index decrease of 0.25% compared to FD1 of 0.33%, FD2 of 0.30%, and FD3 of 0.34%. In a study by Rahmawati et al. (2014) virgin coconut oil used for 30 days resulted in a lower yolk index compared to the present study for 28 days. The FD1 for up to 28 days produced a yolk index of 0.35%, FD2 for up to 28 days produced a yolk index of 0.33%, and FD3 for up to 28 days produced a yolk index of 0.37%. Rahmawati et al. (2014), indicated that using virgin coconut oil with a storage period of 30 days resulted in a yolk index of 0.30%. In addition, a study by Shurmasti et al. (2023) used chitosan with different origins, dosages, and DD for 28 days resulting in a lower yolk index when compared to the present study for 28 days. Shurmasti et al. (2023), conducted a study using chitosan from shrimp shells with a dose of 4%, DD 85%, and storage for 28 days combined with 5% polyvinyl alcohol resulted in a yolk index of 0.35%.

The yolk index in the present study illustrated that preparing eggs with coating can prevent a high decrease in the yolk index as shown in the FD2 and FD3 treatments. The decreasing yolk index value was caused by the yolk vitelline membrane, which was not strong due to the migration of water from the egg white that entered the yolk by diffusion, resulting in yolk enlargement. In addition, long storage of eggs can cause a mushy effect on the yolk which indicates that the yolk index has been damaged, so the yolk index obtained can be small (Mudawaroch et al., 2020). According to Biesiada-Drzazga et al. (2022), the lengthy storage period is the reason for the low yolk index during storage, and excessive storage duration can also result in a low yolk index. Kunz et al. (2023), stated that during egg storage the yolk vitelline membrane can experience the migration of water from the egg white which can enter the yolk, therefore the yolk appears larger. Mudawaroch et al. (2020), reported that during storage the egg yolk causes a mushy effect which indicates that the yolk index obtained can be small so that the quality of the yolk index decreases.

In the current study from 0 days to 56 days FD0 experienced an increase in albumen pH of 8.12 compared to FD1 of 8.13, FD2 of 8.10, and FD3 of 8.17. According to Senevirathne et al. (2022), virgin coconut oil used for 28 days resulted in a lower albumen pH compared to the present study for 28 days. The FD1 for up to 28 days resulted in an albumen pH of 8.11, FD2 for up to 28 days resulted in an albumen pH of 8.08, and FD3 for up to 28 days resulted in an albumen pH of 8.11. Senevirathne et al. (2022), conducted a study using virgin coconut oil with a storage period of 28 days resulting in an albumen pH of 7.17. Likewise, other current research using chitosan with different origins, dosages, and DD for 28 days resulted in higher albumen pH when compared to this study for 28 days. Kilinc et al. (2023), found that using 1.5% chitosan

+ 1.5% *Aloe vera* gel and storage for 28 days resulted in an albumen pH of 10.33.

Albumen pH in the current study indicated that egg preparation with coating can prevent a high increase in albumen pH as seen in the FD2 and FD3 treatments. Carbon dioxide vaporation in the present study was low so the buffer system mechanism was still pleasant. The increase in an albumen pH in the current study was not too high, but changes were observed in the gel structure, therefore the surface of the albumen expanded due to dilution that occurred in the albumen due to CO_2 (carbon dioxide) evaporation and the pH would increase. In addition, CO_2 lost through the pores of the eggshell causes the concentration of bicarbonate ions in the albumen to decrease and damage the buffer system, therefore the pH of the albumen increases. According to Hanifa et al. (2023), the pH of albumen does not increase rapidly because there is no high CO_2 evaporation, but when CO_2 evaporation is significantly high, the pH level of the albumen can swiftly rise. Kar et al. (2023), stated that the low pH value of albumen is due to insignificant changes in the gel structure of albumen. Anggita et al. (2023), reported that the increase in albumen pH due to the pores of the eggshell releasing CO_2 usually occurs in eggs that are not coated. Additionally, an increase in albumen pH can occur if the eggs are stored for too long at room temperature without coating. However, if coating is done, the pH of the albumen can remain stable and not increase.

In the present study from 0 days to 56 days FD0 experienced an increase in yolk pH of 7.05 compared to FD1 of 7.11, FD2 of 7.07, and FD3 of 7.10. Other studies that developed at this time using virgin coconut oil for 35 days resulted in lower yolk pH compared to this study for 42 days. Likewise, other current studies using different doses of chitosan and combinations with a storage time of 28 days resulted in comparable yolk pH when compared to the current study for 28 days. The FD1 for up to 42 days resulted in a yolk pH of 7.06, FD2 for up to 28 days resulted in a yolk pH of 6.89, and FD3 for up to 28 days resulted in a yolk pH of 7.02. Saputri (2011), found that using virgin coconut oil with a storage period of 35 days resulted in a yolk pH of 6.36. Awwaly et al. (2024), illustrated that using 1% chitosan + 1% casein + garlic essential oil and storage for 28 days resulted in a yolk pH of 6.83.

pH of yolk in the present study indicated that preparing eggs with coating can prevent a high increase in yolk pH as shown in the FD2 and FD3 treatments. The present study used room temperature, therefore high temperature at the time of the study (egg storage) contributed to a larger loss of CO_2. In addition, the high pH value of the yolk indicated that there is evaporation of water and CO_2 gas contained within the egg. According to Kim et al. (2024), the long storage of eggs would cause the pH of the yolk to increase because the pores of the eggshell can open as long as the storage lasts. Oliveira et al. (2020), indicated that egg storage carried out at room temperature would provide an opportunity for CO_2 to disappear so quickly that the pH value of the yolk would increase and storage of eggs could be carried out at room temperature with a coating treatment that would be able to control evaporation. Wibowo et al. (2023), reported evaporation of the egg's contents including water and CO_2 gas will also increase contained in the egg and if the egg is coated the evaporation that occurs will be resolved and the pH value of the egg yolk will also not increase.

In the present study from 0 days to 56 days FD0 decreased the yolk color by 6.11 compared to FD1 by 6.33, FD2) by 6.22, and FD3 by 6.44. Another current study using virgin coconut oil for 40 days resulted in lower yolk color compared to the present study for 42 days. In addition, other current studies using different doses of chitosan and combinations with a storage time of 14 days resulted in comparable yolk color when compared to this study for 14 days. The FD1 coating using virgin coconut oil for up to 42 days produced a yolk color of 6.78, FD2 using 1.5% chitosan + 1% stearin for up to 14 days produced a yolk color of 7.44 and FD3 using 3% chitosan + 1% stearin for up to 14 days produced a yolk color of 7.55. Todja et al. (2019), indicated that using virgin coconut oil with a storage period of 40 days resulted in a yolk color of 3.00. Thohari et al. (2022), conducted a study using 1% chitosan + 4% casein + 1% TiO_2 and storage for 14 days resulted in a yolk color of 7-9.

Yolk color in the present study did not decrease rapidly because the migration of H_2O from albumen to yolk was not significant. Different yolk color values are caused by the high productivity of chickens and low xanthophyll pigment content in the diet. The difference in yolk color in the present study is attributed to the different metabolic rates of the chickens, resulting in varying abilities to absorb xanthophyll pigments. Virgin coconut oil caused a distinctive aroma of coconut oil while treatment FD3 caused a distinctive aroma of chicken eggs, thus a reduction would be observed in the level of consumer preference. According to Li et al. (2022), the rapidly decreasing yolk color is due to the migration of H_2O from albumen to the yolk, so the resulting yolk color can also be small and pale. Yunitasari et al. (2023), stated that low yolk color values can occur due to high chicken

productivity factors and low xantophyl pigment content in the diet, so it needs to be considered so that the yolk color value does not decrease. Dansou et al. (2023) reported that each chicken has a different metabolic condition, so the ability to absorb xantophyl pigments in chickens is not similar.

CONCLUSION

The chitosan-stearin coating can maintain the quality of chicken eggs during storage for up to 56 days. Using a coating formula with a treatment level of 3% chitosan + 1% stearin indicated the best results in maintaining the quality of eggs during storage at room temperature.

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Authors' contributions

Trioso Purnawarman, Muheri Indra Aja Nasution, Mochammad Sriduresta Soenarno, and Siswanto contributed to designing the study, analyzing the study, and preparing the manuscript. Trioso Purnawarman, Muheri Indra Aja Nasution, Mochammad Sriduresta Soenarno, Siswanto, Yunilas, Uswatun Hasanah, and Sri Wahyuni analyzed the samples in the laboratory and contributed to the drafting and critical checking of the manuscript. All authors confirmed the final draft of the manuscript before submission to the journal.

Competing interests

The authors declared no competing interests in the publication of the present study.

Ethical considerations

All the authors had checked and confirmed the article through ethical issues such as plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy before the submission.

Availability of data and materials

All the data and materials are available on request from the corresponding author.

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