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RESEARCH ARTICLE

Effect of eggshell coating material and storage condition on egg quality traits and sensory attributes of chicken eggs

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ABSTRACT

Egg quality changes with the use of different coating material (uncoated vs. coconut oil-coated vs. beeswax-coated) held at two storage temperatures (27 vs. 4 °C) over five storage periods (SP) (0, 7, 14, 21 and 28 d) were evaluated. Two hundred and ten shell eggs (62.5±1.0 g) obtained from 53-weeks old Hy-line White layers were tested. The experimental design was 6x5 factorial arrangements of treatments which evaluated six egg preservation techniques and five SP in a total of 30 treatments, with seven eggs (n=7) each. Six treatments consisted of Uncoated eggs stored at room temperature (RMT:27 °C ±1) (T1), Uncoated eggs stored at refrigerator temperature, (RFT: 4 °C) (T2), Coconut oil coated eggs stored at RMT (T3), Coconut oil coated eggs stored at RFT (T4), Beeswax coated eggs stored at RMT (T5) and Beeswax coated eggs stored RFT (T6). Storing eggs at RMT for 28 d resulted the highest weight loss (P<0.05). Coating eggs with beeswax significantly (P<0.05) increased the shell thickness and the shell ratio. Coating resulted the lowest albumen pH (P<0.05). The albumen index in T1 was significantly (P<0.05) reduced from 7 d. T4, when stored for 0 d, 14 d and 28 d, resulted the highest albumen ratio (P<0.05). Increasing SP from 0 d to 28 d reduced the yolk index in T1. The study concluded that, egg coating, when combined with refrigeration, preserves egg quality for 28 d. Beeswax coated-refrigerated eggs are the best in preserving egg quality. Coconut oil coated eggs stored at RMT attracted panelists the most.

***Keywords**: Beeswax, coating, coconut oil, egg quality, chicken*

INTRODUCTION

Poultry eggs are considered the most low cost and the world's most perfect dietary source of protein (Ariyachandra *et al.*, 2022). Though eggs from different poultry species are available, chicken eggs are the most consumed egg type in Sri Lanka (Jayasena *et al.*, 2012; Livestock Statistical Bulletin, 2019).

Food quality can be defined as the '*Sum of characteristics of a given food source which influence the acceptability or preference for that particular food source by the consumers*' and is determined preferably by its cost, tastiness and the wholesomeness (Chukwuka *et al.*, 2011; Abdullah *et al.*, 2018). In commercial egg industry, egg quality is the best endorsed by routine egg grading practices. Grading of eggs is mainly performed based on the egg weight and the quality of eggshell, albumen, yolk, and the air cell (Stadelman, 1995; Joubrane *et al.*, 2019). It is well known

that those internal and external egg quality traits are declined from the moment of egg laying. Eggs are highly perishable and the perishability can be influenced by unfavorable environmental conditions, particularly the high ambient temperatures and the storage time (Obanu and Mpieri, 1984; Eke *et al*., 2013). In Sri Lanka, chicken eggs are stored mostly at room temperatures. However, the perishable food items like eggs require quick cooling and refrigerator treatments over storage to maintain the quality. It is well known that the egg deterioration occurs faster at elevated temperatures (30 to 40 °C) than at refrigerated temperatures (0 to 4 °C) (Akter *et al*., 2014). Moreover, the length of the storage period has been revealed to exert a significant effect on loss in egg weight, albumen and yolk pH (Faris *et al*., 2011). During egg storage, the strength of the vitelline membrane declines, making the yolk more susceptible for breaking (Kirunda and McKee, 2000).

The eggshell itself is a natural protective, mineralized structure, which provides a sound protection against to physical damages and microbial penetration. Generally, the eggs, once they are laid, are collected frequently and are directed to the market after the egg shells are hand-buffed or wet-cleaned to prevent contamination. It is well known that improper cleaning procedures lead to reduction of the shelf life of table eggs and increases the susceptibility to be damaged during handling. Eggshell contains numerous microscopic pores (La Scala *et al.*, 2000) where both hand buffing and wet cleaning may lead to the removal of cuticle exposing those minute pores to the external environment. Exposure of pores (i) retards the protection of eggs against microbial penetration and (ii) allows moisture and CO_2 to permeate through the egg shell. The loss of CO_2 through the shell pores interrupts the carbonic acid equilibrium in egg albumen leading to breakdown of carbonic acid. Dissociation of carbonic acid releases more CO_2, changing the egg from an almost neutral pH 7.6 to a very alkaline pH 9.7 (Obanu and Mpieri, 1984). The degree of CO_2 and moisture loss through the egg shell determines the degree of changes in albumen, yolk and weight loss of eggs (Al-Hajo *et al*., 2012). Penetration of microorganism through the shell pores may also contribute to quality deterioration. Studies reported that the growth of microbes in eggs can be influenced by the storage environment (Eke *et al.,* 2013). Therefore, egg sealing is frequently recommended to slow down the egg quality deterioration over the storage (Shittu and Ogunjinmi, 2011; Eke *et al*., 2013).

The need of preservation of eggshells has led to the development of different coating materials. Coating is a surface treatment method with low cost. Coating using edible films had been shown to maintain the functional properties of food by retarding the moisture loss and gas permeation (O_2 and CO_2), and furthermore these edible films are delaying the volatilization of aromatic components (Al-Hajo *et al*., 2012). A number of research has been conducted in the past to investigate the effect of different coating materials such as propolis (Suryani *et al*., 2017), beeswax (Mudannayaka *et al*., 2016), Alovera gel (Mudannayaka *et al*.,

2016) mineral oils (Wardy *et al*., 2010; Wahba *et al*., 2014), whey protein concentrate (Wardy *et al*., 2010; Almeida *et al*., 2015), cassava and yam starches (Brito-Mota *et al*., 2017), whey protein-rice bran oil (Safavi and Javanmard, 2016), petroleum jelly and paraffin wax (Biladeau and Keener, 2009; Shittu and Ogunjinmi, 2011), soybean oil (Wardy *et al*., 2010), shellac and chitosan (Bhale *et al*., 2003; Saeed *et al*., 2016) and rice protein (Pires *et al*., 2019) on egg quality traits. However, investigating the potential of using local materials for egg preservation and interactive effects between types of edible coating held at different storage temperatures for different storage periods are highly limited. Most of the currently used coatings have been focused on preventing dehydration and respiration instead of inhibiting microbial activity. Coating materials made up of nature-based materials were found to be better in their antibacterial property as compared to than to those of other synthetic coatings.

Coating materials containing antibacterial substances enhance the preservation of eggshells other than sealing of eggshell pores. Beeswax is a product of honey bees and a natural wax composed of a mixture of esters, hydrocarbons, fatty acids, alcohol and other compounds like aromatic substances and pigments and rich with natural antimicrobial substances (Zanoschi *et al*., 1991; Szulc *et al*., 2020). It has considerable antibacterial and antifungal effects (Kacániová *et al*., 2012). Due to aforementioned properties beeswax has a potential to be used as a coating material for eggs. Coconut oil which is a plant-based oil derived from coconut (*Cocos nucifera*) has also been confirmed to possess antimicrobial, antiviral and antiprotozoal properties (Oyi *et al*., 2010; Widianingrum *et al*., 2019) therefore has a potential to be used for egg coating. The present study was conducted to investigate the effect egg coating (uncoated *vs.* coconut oil *vs.* beeswax) and the holding temperature (4 *vs.* 27 °C) on egg quality and sensory attributes of chicken eggs stored for different storage periods (0, 7, 14, 21 and 28 d).

MATERIALS AND METHODS

Sampling of eggs

Two hundred and ten (210) fresh white chicken eggs obtained from 53-weeks old Hy-line White layers managed in a large-scale commercial poultry farm were used. Upon collection, hand-buffed eggs were individually weighed (62.5±1g) (Model XB 320M, Precisa, Switzerland) and were randomly divided into six treatments with 35 eggs/treatment.

Experimental design

The experiment was conducted in a completely randomized design in a 6x5 factorial arrangement of treatments, evaluating six egg preservation techniques against five storage periods. Six preservation techniques (treatments) consisted of Uncoated Eggs stored at room temperature (RMT:27 °C±1) (T1), Uncoated eggs stored at refrigerator temperature, (RFT: 4 °C) (T2), Coconut oil coated eggs

stored at RMT (27 °C±1) (T3), Coconut oil coated eggs stored at RFT (4 °C) (T4), Beeswax coated eggs stored at RMT (27 °C±1) (T5) and Beeswax coated eggs stored at RFT (4 °C) (T6). The treatments were tested for five storage periods (0, 7, 14, 21 and 28 d) in a total of 30 treatments, with seven eggs (n=7) each.

Preparation of egg coating materials

Coconut oil: Food-grade coconut oil (transparent, colourless and odorless) obtained from a super market was poured into a 250 mL beaker and the eggs were immersed individually for few seconds and allowed for draining.

Beeswax: Beeswax was cut into slim slices using a knife. The cut pieces were introduced into a clean 250 mL beaker, immersed in a boiling water bath at 40 °C. Liquidized beeswax was cooled to RMT until it transforms into semi-solid beeswax. A total of 70 eggs were immersed individually in beeswax for few seconds and were subsequently coated with beeswax by rubbing wax on the shells manually (Mudannayaka *et al.*, 2016).

Storage of coated eggs

All coated eggs were dried at RMT for 1 h. Uncoated eggs held at RMT served as the control. All the eggs were labeled individually, placed in trays at narrow end down position and were stored either at RMT (T1, T3 and T5) or RFT (T2, T4 and T6) over four weeks period. Seven eggs (n=7) from each treatment were labeled as a group to obtain measurements weekly. A total of 42 eggs from six treatments were analysed in consequent weeks. 0 d measurements were taken 6 h after coating and other eggs ware measured respectively on days 7, 14, 21 and 28 d of the experiment. Egg quality traits were measured at the end of each storage period.

Measuring egg quality traits

Eggs were weighed before storage and at the end of each storage period to determine the weight loss using an analytical balance (Model XB 320M, Precisa, Switzerland). Egg weight loss was calculated in grams as the difference between initial weight and the weight obtained after the storage period and presented as a percentage (Caner and Yüceer, 2015). The egg length and width of each intact egg was measured using a venire caliper (Model CD6"CSX, Mitutoyo, Japan) to determine the shape index. Egg shell thickness of individual egg was measured using a digital micrometer screw gauge (Model IP65, Mitutoyo, Japan) and the egg shell weight was measured using an analytical balance (Model XB 320M, Precisa, Switzerland). Shell ratio (%) and Shape index (%) of eggs were calculated as described by Kul and Seker (2004). The Haugh Unit (HU) was calculated as 100 log (H – 1.7 $W^{0.37}$ + 7.57), the equation described by Al-Hajo *et al*. (2012) where, H is the albumen height (mm) and W is the weight (g) of egg. Albumen pH was measured using a pre-calibrated digital pH meter (PH100: ExStik, EXTECH, USA) at 25 °C. The albumen height was measured using a manual

spherometer (Model, 1002947, 3B Scientific GmbH, Germany) and its diameter was measured with the venire caliper (Model CD6"CSX, Mitutoyo, Japan), before separating into yolk and albumen to assess albumen index (Kul and Seker, 2004). Albumen weights were measured using an analytical balance (Model XB 320M, Precisa, Switzerland) to calculate the albumen ratio (Kul and Seker, 2004). Upon breaking out, the yolk height of individual egg was measured using a digital caliper and its diameter was measured using an analog venire caliper. The yolk was separated from albumen to obtain the weight (Model XB 320M, Precisa, Switzerland). The yolk index and yolk ratio were calculated using the formulas described by Kul and Seker (2004). The colour of the egg yolk was determined using a Roche yolk colour fan having scale on which 15 graded colours (Roche and Company Ltd., Switzerland).

Sensory evaluation

A sensory evaluation was conducted to investigate the external and internal sensory attributes of coated and uncoated eggs. Sensory evaluation was done separately for a total of 36 boiled (held for 14 d) and fresh eggs. Thirty un-trained panelists were used to evaluate the fresh egg surface appearance/shell colour, shell texture, shell odor, broken eggs odor, and overall acceptability on seven-point hedonic scale. Thirty untrained panelists were also used to evaluate the egg taste, appearance, colour, albumen texture and finally the overall acceptability.

Data analysis

The data were analysed statistically using Statistics Analysis Software 9.0 version (SAS, 2002). Two-way analysis of variance (ANOVA) was conducted to determine the effect of preservation technique and storage period with their interaction. Differences were considered significant at $P<0.05$ and significant differences between means were separated by Duncan's multiple range test. The sensory data were analysed by Friedman test using Minitab 17 software.

RESULTS AND DISCUSSION

Shell quality traits

The effects of six treatments *vs.* storage period on weight loss, shape index, shell thickness and shell ratio of eggs are presented in Tables 1 and 2.

***Weight loss (%)*:** Weight loss is one of the excellent measurements to monitor the changes in quality of fresh eggshells during storage. The losses and diffusion of water and gases in the inner egg content during the ageing process may result reduction of the egg volume and expansion of the air cell, resulting loss of weight of the whole egg (Adamski *et al.*, 2017).

When main effects are concerned, weight loss was significantly ($P<0.001$) affected by the treatment and the storage period ($P<0.001$). A significant

(P<0.001) interaction between storage technique and the storage period was observed for weight loss.

Table 1: Effect of preservation technique and storage period on external quality traits of chicken eggs[1].

Treatment	Storage Period (d)	Weight Loss (%)	Shape Index (%)	Shell Thickness (mm)	Shell Ratio (%)
	0	0.16^{hi}	76.3	0.54^{cdefg}	9.54^{ghijk}
	7	1.18^{d}	77.0	0.59^{cd}	10.43^{e}
T1	14	2.65^{c}	77.3	0.54^{cdefg}	9.54^{ghijk}
	21	3.14^{b}	74.3	0.56^{cde}	10.22^{ef}
	28	4.59^{a}	74.4	0.59^{c}	10.08^{efgh}
	0	-0.34^{jkl}	74.4	0.54^{cdefg}	9.80^{fghijk}
	7	0.58^{fg}	76.9	0.54^{cdefg}	9.46^{ijk}
T2	14	0.94^{ef}	77.2	0.57^{cde}	$9.84^{efghijk}$
	21	1.18^{d}	76.6	0.54^{cdefg}	9.43^{jk}
	28	1.54^{d}	76.8	0.55^{cdef}	9.43^{jk}
	0	0.00^{ijk}	78.5	0.52^{efg}	9.98^{efghij}
	7	0.14^{hi}	76.4	0.55^{cdef}	10.12^{efg}
T3	14	0.19^{ghi}	75.4	0.56^{cde}	10.04^{efghi}
	21	0.25^{ghi}	74.2	0.49^{g}	10.15^{ef}
	28	0.22^{ghi}	76.9	0.55^{cdefg}	9.64^{fghijk}
	0	-0.36^{jkl}	76.3	0.54^{cdefg}	9.89^{efghij}
	7	0.11^{hi}	76.0	0.50^{fg}	$9.83^{efghijk}$
T4	14	0.01^{ijk}	76.3	0.53^{efg}	9.31^{k}
	21	0.03^{hij}	75.6	0.54^{defg}	9.99^{efghij}
	28	0.18^{ghi}	76.1	0.57^{cde}	9.50^{hijk}
	0	0.00^{ijk}	76.1	0.91^{a}	12.81^{d}
	7	0.17^{ghi}	75.3	0.77^{b}	13.53^{ab}
T5	14	0.45^{gh}	75.7	0.88^{a}	12.85^{cd}
	21	0.25^{ghi}	76.0	0.92^{a}	13.46^{ab}
	28	0.33^{ghi}	76.6	0.89^{a}	13.45^{abc}
	0	-0.41^{kl}	76.1	0.92^{a}	13.07^{bcd}
	7	-0.35^{jkl}	76.1	0.81^{b}	13.57^{ab}
T6	14	-0.04^{ijk}	76.2	0.91^{a}	13.77^{a}
	21	-0.70^{l}	77.0	0.90^{a}	13.69^{a}
	28	-0.56^{l}	75.6	0.89^{a}	13.50^{ab}
SEM[2]		0.15	1.02	0.02	0.22

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6=Beeswax coated, refrigerated temperature stored.

[a-l]Means in a column not sharing a common superscript are significantly different (P<0.05).

[1]Each value represents the mean of seven eggs.

[2]SEM=Pooled standard error mean.

The highest weight loss on 0 d was recorded from T1 which was similar (P>0.05) to that of T3 and T5. The weight loss on 0 d was minimal and similar between T2, T4 and T6 treatments. On 7 d, significantly the highest and the lowest weight losses (P<0.05) were observed in T1 and T6 eggs, respectively. On 14 d, the highest (P<0.05) weight loss was in T1 eggs. The minimum weight loss on 14 d was observed in T3, T4 and T6 treatments. The maximum and minimum weight losses in eggs held for 21 d were observed from T1 and T6, respectively. On 28 d, the maximum and minimum weight loss was observed from T1 and T6, respectively.

Table 2: Main effects of preservation technique, storage period and their interactions on external quality traits of chicken eggs[1].

Main effects	Weight Loss (%)	Shape Index (%)	Shell Thickness (mm)	Shell Ratio (%)
Method of preservation				
T1	2.34	75.9	0.57	9.96
T2	0.78	76.2	0.55	9.59
T3	0.16	76.3	0.53	9.99
T4	-0.01	76.0	0.53	9.70
T5	0.24	76.0	0.87	13.22
T6	-0.41	76.2	0.89	13.52
SEM[2]	0.07	0.46	0.01	0.10
Storage period				
0d	-0.16	76.3	0.66	10.85
7d	0.31	76.1	0.63	11.16
14d	0.70	76.3	0.67	10.89
21d	0.69	75.6	0.66	11.16
28d	1.05	76.1	0.67	10.93
SEM[2]	0.06	0.42	0.01	0.09
Probabilities, P<				
Method of preservation	***	NS	***	***
Storage period	***	NS	**	*
Method of preservation × Storage period	***	NS	***	*

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6=Beeswax coated, refrigerated temperature stored.

NS, not significant; *P < 0.05; **P < 0.01; ***P < 0.001.

[1]Each value represents the mean of seven eggs.

[2]SEM=Pooled standard error mean.

Overall, the eggs from T6 demonstrated a negative weight loss throughout the period of storage. More pronounced positive weight loss was observed in T1 over the storage period.

These results are almost in close agreement with Tabidi (2011) who reported that there is a highly significant difference existed between the average percentage loss for eggs stored at the RMT and the ones stored in refrigerator. According to Tabidi (2011), the average losses in weights of eggs stored at the RMT and at the RFT are 4.76 and 1.54%, respectively. Adamski *et al*. (2011) also reported that the proportional loss in the egg weight during storage increased with every week and significant differences were observed between the first two weeks and the last one, which testified to the highest proportional weight loss in the final period of storage. The present study showed the lowest weight losses in coated eggs. Similar results were obtained by Obanu and Mpieri (1984) who found that the vegetable oil coatings minimized the weight loss of eggs (0.013-0.016 g) compared with that of the uncoated (0.186 g) held for 36 d storage period at 25-32 °C. Jirawatjunya (2013) described that the weight loss of eggs significantly increased over 5 weeks of storage period when stored at 25 °C. However, the rate of weight loss (%) in coated eggs was slower than that of uncoated eggs, which may probably due to sealing pores of eggshell by coating. Coating prevents the movement of CO_2 and water from the eggs resulting a loss in weight. Lipid-based film types coating materials are more resistant to moisture barriers because of their hydrophobic structure (Jirawatjunya, 2013). Further, the present study showed increased weight loss when eggs were held at RMT than stored at RFT. A similar result was obtained by Jin *et al.* (2011) who reported that the egg weight significantly decreased with increasing storage time and temperature. According to those researchers, increasing storage temperature up to 29 °C dramatically increased the loss of egg weight from 1.74 to 3.67% at 5 and 10 d of storage time, respectively. This may be due to faster moisture evaporation through shell pores when the eggs are held at RMT.

***Shape index (%)*:** The effect of preservation technique and storage period on egg's shape index is presented in Table 1 and 2. The present study indicated that the shape index of the treated eggs and control eggs were not significantly (P>0.05) different. Similarly, there was no significant (P>0.05) effect of the period of storage on shape index. Furthermore, the results indicated that no significant interaction exists between treatments and the storage period (Table 2). This finding is similar to the findings of Tabidi (2011) who reported the nonexistence of the significant differences among the shape index of eggs stored in a room (74.53%) or a refrigerator (73.87%). There was no impact for the period of storage on the shape indices of eggs held at the room or the refrigerator temperatures. Jayasena *et al*. (2012) reported that the shape index of a standard egg which is normally recorded as 74%. The results of the present study also showed that the shape index values obtained for different treatments are much closer to the standard shape index value.

***Shell thickness (mm)*:** Shell thickness measurement is an indirect method for measuring shell quality. When main effects are concerned, the mean shell thicknesses were significantly (P<0.001) different among the treatments (Table 1

and 2). The shell thicknesses of treated eggs were significantly (P<0.01) affected by the length of the storage period. A significant (P<0.001) interaction has been observed between the treatments and the storage periods (Table 2).

Shell thicknesses of T5 and T6 treatments were similar (P>0.05) between respective storage periods starting from 0 d to 28 d, but higher (P<0.05) than to that of other four treatments. As described by Jayasena *et al*. (2012), the shell thickness of chicken eggs ranges from 0.30 to 0.40 mm when held at 30 °C. Shell thickness and shell weights are known to have a direct correlation. Lall (2014) described that the storage period and preservation method significantly affected the shell thickness of eggs. The results of the present study indicated that there was no significant effect of storage temperature on shell thickness, when the eggs were held at room and the RFT. Similarly, Akter (2014) and Tabidi (2011) reported that the shell thickness of eggs held at two different temperatures (4 and 28-31 °C) were not affected by the storage temperature. Findings of the present study are in agreement with Çağlayan *et al*. (2009) and Dudusola (2009) who reported that the storage time and temperature had no effect on shell thickness of partridges and Japanese quail eggs, respectively. Beeswax coated eggs had the highest shell thickness throughout the storage period. This finding is in agreement with Biladeau and Keener (2009) who reported that the wax-coated eggs had the highest shell strength and the uncoated eggs had the lowest. According to these researchers, the wax coating was approximately 10 times thicker than the whey protein isolate or soya protein isolate. Application of a thick layer of wax coating increased the shell thickness of T5 and T6 eggs.

***Shell ratio (%)*:** When main effects are concerned, the preservation technique (P<0.001) and the storage period (P<0.05) had a significant effect on egg shell ratios of eggs (Table 1 and 2).

A significant (P<0.05) interaction between the preservation technique and the storage period was also observed. Unlike other treatments, the shell ratios of T2 (P>0.05) and T3 (P>0.05) were unaffected by the storage period. Shell ratios of T5 and T6 eggs held from 0-28 d were significantly (P<0.05) higher than that of T1, T2, T3 and T4 (Table 1). This can be explained by the fact that application of a thick layer of beeswax tended to increase the shell weight. However, shell ratios between T3 and T4 eggs for their respective storage period were similar except in 14 d. A similar trend was observed between T5 and T6 eggs for their shell ratios.

However, the findings of the present study were in close agreement with Akter *et al.* (2014) who reported that shell weight as a percentage was not affected by the storage time and the temperature. Akyurek and Okur (2009) found that the shell weight does not change with storage temperature and time. Similar results were obtained by Scott and Silversides (2000) who reported that no effect of storage time on egg shell weight. However, in contrast, Lall (2014) observed that there was a significant effect of storage period and preservation method on shell weight

percentage. Jin *et al.* (2011) found a significant decrease in shell weight with increasing storage period.

Albumen quality traits

The effect of preservation technique and storage period on egg albumen quality traits are presented in Table 3 and 4.

Table 1: Effects of preservation technique and storage period on albumen quality traits of chicken eggs[1].

Treatment	Storage period (d)	Haugh Unit	Albumen pH	Albumen Index (%)	Albumen Ratio (%)
	0	79.0^{abcd}	8.12^{def}	7.47^{ghijklm}	62.3^{ab}
	7	67.2^{g}	8.36^{cde}	5.12^{n}	61.7^{abcdefgh}
T1	14	61.6^{h}	8.86^{ab}	3.69^{o}	59.7^{klmno}
	21	56.1^{i}	8.54^{c}	2.98^{op}	60.3^{fghijklmn}
	28	51.9^{i}	8.95^{a}	2.25^{p}	59.0^{nop}
	0	83.0^{ab}	8.15^{def}	9.20^{ab}	61.8^{abcdefg}
	7	79.1^{abcd}	8.15^{def}	7.8^{1efghijk}	62.1^{abc}
T2	14	80.1^{abcd}	8.29^{cde}	7.92^{defghij}	62.9^{a}
	21	73.6^{ef}	8.55^{bc}	6.61^{lm}	60.7^{cdefghijkl}
	28	80.9^{abc}	8.40^{cd}	8.01^{cdefghi}	59.9^{jklmno}
	0	82.5^{ab}	7.93^{fg}	9.00^{abcd}	61.0^{bcdefghijk}
	7	78.0^{bcde}	7.73^{gh}	7.46^{hijklm}	60.6^{defghijklm}
T3	14	76.2^{cdef}	7.42^{hijk}	7.38^{hijklm}	61.6^{bcdefgh}
	21	75.9^{cdef}	7.57^{hi}	7.14^{ijklm}	61.2^{bcdefghij}
	28	75.1^{def}	7.17^{klm}	6.64^{lm}	61.2^{bcdefghij}
	0	80.1^{abcd}	7.98^{efg}	8.10^{bcdefghi}	61.8^{abcde}
	7	82.3^{ab}	7.31^{ijklm}	9.33^{a}	61.4^{bcdefghi}
T4	14	84.1^{a}	7.37^{ijk}	9.23^{ab}	63.2^{a}
	21	83.5^{a}	7.20^{jklm}	9.14^{abc}	60.3^{ghijklmn}
	28	83.8^{a}	7.25^{jklm}	9.15^{abc}	61.9^{abcd}
	0	80.8^{abc}	7.90^{fg}	8.53^{abcdefgh}	60.0^{ijklmno}
	7	76.0^{cdef}	7.51^{hij}	7.43^{hijklm}	59.7^{klmno}
T5	14	78.0^{bcde}	7.14^{klm}	7.61^{fghijkl}	59.5^{lmno}
	21	72.4^{fg}	7.05^{lm}	6.73^{klm}	59.2^{mno}
	28	70.9^{fg}	6.60^{n}	6.40^{m}	57.7^{p}
	0	79.5^{abcd}	7.70^{gh}	8.63^{abcdefg}	59.9^{ijklmno}
	7	83.8^{a}	7.20^{jklm}	9.64^{a}	58.7^{op}
T6	14	81.9^{ab}	7.35^{ijkl}	9.05^{abcd}	60.3^{efghijklmn}
	21	81.2^{abc}	7.01^{m}	8.90^{abcdef}	60.3^{hijklmn}
	28	80.9^{abc}	7.24^{jklm}	8.94^{abcde}	60.1^{ijklmno}
SEM[2]		1.93	0.11	0.42	0.53

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T 4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6=Beeswax coated, refrigerated temperature stored.

[a-p]Means in a column not sharing a common superscript are significantly different (P<0.05).

[1]Each value represents the mean of seven eggs.

[2]SEM=Pooled standard error mean.

Table 4: Main effects of preservation technique, storage period and their interactions on albumen quality traits of chicken eggs[1].

Main effects	Haugh Unit	Albumen pH	Albumen Index (%)	Albumen Ratio (%)
Method of preservation				
T1	63.2	8.57	4.30	60.6
T2	79.3	8.31	7.91	61.5
T3	77.5	7.57	7.52	61.1
T4	82.8	7.42	8.99	61.7
T5	75.6	7.24	7.34	59.2
T6	81.5	7.30	9.03	59.9
SEM[2]	0.86	0.05	0.19	0.24
Storage period				
0d	80.8	7.96	8.49	61.1
7d	77.8	7.71	7.80	60.7
14d	77.0	7.74	7.48	61.2
21d	73.8	7.65	6.92	60.3
28d	73.9	7.60	6.90	59.9
SEM[2]	0.79	0.05	0.17	0.21
Probabilities, *P*<				
Method of preservation	***	***	***	***
Storage period	***	***	***	**
Method of preservation× Storage period	***	***	***	***

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6= Beeswax coated, refrigerated temperature stored.

NS, not significant; **P*<0.05; ***P*<0.01; ****P*<0.001.

[1]Each value represents the mean of seven eggs.

[2]SEM=Pooled standard error mean.

***Haugh Unit (HU)*:** When main effects are taken into account, a significant (*P*<0.001) effect has been observed between preservation technique and storage period for HU (Table 3 and 4). A significant (*P*<0.001) interaction was also evident between treatment and storage periods.

Haugh unit is expressed relating the whole egg weight and height of the thick albumen. It is a measure of albumen quality. According to United States Department of Agriculture (USDA, 2000) quality standards for shell eggs, higher HU values represent high quality egg with better albumen quality. Over the entire storage period of 28 d, HU of T2 (except in 21 d), T4 and T6 resulted the highest HU values which is indicative of that refrigeration of either uncoated/coated eggs which preserved the HU up to 28 d. All the treatments have resulted the highest HU on 0 d which were similar (*P*>0.05) between treatments. The results demonstrated that the HU decreased significantly (*P*<0.05) when the uncoated eggs were held at RMT. This finding is in agreement with those of Pius and Olumide (2017) who observed a decline in albumen height and HU values with advancement of storage. Similar results were also described by some other researchers. Jirawatjunya (2013) reported that the loss of albumen quality is in a relationship with egg's age, time, temperature, humidity, and storage handling.

Torrico (2010) described that the temperature and CO_2 movement directly influence the rate of change in the albumen quality.

***Albumen pH*:** The pH of albumen in newly laid eggs ranges between 7.6 and 8.5 (Waimaleongora-Ek *et al*., 2009). However, the albumen pH of T1 and T2 increased from the initial value of pH 8.12 to pH 8.95 in T1 and pH 8.15 to pH 8.40 in T2 over 28 d of storage period (Tables 3 and 4). This change may due mainly to breaking down of the equilibrium of the carbonate-bicarbonate-buffer system and converting carbonic acid into CO_2 which evaporate or escape through the pores (Biladeau and Keener, 2009). This may lead albumen pH to increase significantly in T1 and T2 treatments. Comparatively, a higher pH increment observed in T1 at 14 d and 28 d than for respective periods of T2 may be due mainly to escape of higher amount of CO_2 from eggs when they were stored at RMT than RFT. A similar result was obtained by Akter *et al.* (2014) who reported that the pH of egg albumen can also be influenced by temperature additional to the storage time.

The albumen pH of T3 eggs was significantly (P<0.05) different from T1 and T2 and the albumen pH of T3 changed from pH 7.93 to pH 7.17 at the end of 28 d of storage period. A similar result was reported by Jirangrat *et al.* (2010) who described that the albumen pH of mineral oil coated eggs slightly decreased from 8.71 to 8.64 after five weeks of storage at RMT. Changes in albumen pH may occur due to continuing breakdown of the constituents in albumen or a change in bicarbonate-buffer system (Biladeau and Keener, 2009). However, as described by Torrico (2010), temperature and CO_2 movement may directly influence the rate of change in the albumen.

***Albumen index (%)*:** A significant (P<0.001) effect was observed from the treatment and storage period on albumen index. A significant (P<0.001) interaction has also been observed between the preservation technique and the storage period (Tables 3 and 4). Overall, the highest albumen index values were reported from T4 (except in 0 d) and T6 eggs (P>0.05) over the storage periods. Obviously, the albumen index in T1 was significantly (P<0.05) reduced from 7 d onwards, as compared to the rest of eggs. From 7 d onwards, the coated eggs kept refrigerated had the higher albumen index values (P<0.05) compared to than those stored in RMT (T3 *vs.* T4 and T5 *vs.* T6). However, when eggs are coated with coconut oil and beeswax, the albumen index values were tended to decrease numerically with increasing the length of storage.

The present findings are in an agreement with the results reported by Chauhan (2014) who stated that the albumen index was significantly decreased with increasing storage period. Similar results were obtained by Lall (2014) who reported that there was a significant effect existed between storage period and albumen index. Jayasena *et al.* (2012) observed a reduction of albumen index with the storage period at 30 °C. Lakhotia *et al.* (1982) described that albumen index

was significantly decreased with increasing storage periods. However, water loss from the egg, or movement of water from albumen to yolk might be attributed to this result.

***Albumen ratio (%)*:** Albumen ratio was significantly (P<0.001) affected by the preservation technique (Table 3 and 4). A significant (P<0.01) difference was found for the storage period. Further, the albumen ratio was affected by the interaction effect between the treatment, and the period of storage. The highest albumen ratios were reported from T1 (0 and 7 d), T2 (0 to 14 d) and T4 (0, 14 and 28 d). Refrigeration of uncoated eggs improved the albumen ratio on 14 d than the same of T1.

The present findings are in an agreement with the results reported by Akter *et al*. (2014) who have described that the albumin weight was significantly affected by the storage time. This loss of weight in albumen occurs due to the loss of solvents from the albumen, which may ultimately decrease the weight of the albumen in egg by increasing the weight of yolk. Similarly, Lall (2014) reported that the mean albumen percentage for local chicken eggs was 61.49% when oil coated and was 59.36%, in control held at 7 d of storage. However, albumen% was found to be influenced significantly by the storage period. However, this result is inconsistent with the results of the present study. Further, findings of the present study also showed within treatment differences. Scott and Silversides (2000) reported that the fresh eggs had less albumen than those stored for 1d, but thereafter storage was associated with lower albumen weight and albumen weight decreased with storage.

Yolk quality traits

The effects of preservation technique and storage period on yolk quality traits are presented in Tables 5 and 6.

***Yolk index (%)*:** Yolk index values are used to interpret the spherical nature of egg yolk and are related to the ratio of yolk height and width (Stadelman, 1995). Yolk index of tested eggs were significantly (P<0.001) affected by the treatments and the storage period. A significant (P<0.001) interaction was observed between the preservation technique and the storage period (Table 5 and 6).

On 0 d, yolk index between tested treatments were similar (P>0.05). From 7 d onwards, refrigeration significantly (P<0.05) improved the yolk indices of T2, T4 and T6 than to each's respective counterpart held at RMT. However, as compared to the other treatments, it has been noted that the yolk index of T1 significantly (P<0.05) reduced yolk index over the period (7 to 28 d) of storage.

Table 5: Effects of preservation technique and storage period on yolk quality traits of chicken eggs[1].

Treatment	Storage Period (d)	Yolk Index (%)	Yolk Ratio (%)	Yolk Colour
	0	40.7^{fghij}	$28.2^{efghijkl}$	13.4
	7	30.5^{o}	$27.9^{fghijkl}$	13.6
T1	14	22.3^{p}	30.89^{ab}	13.4
	21	15.1^{q}	29.5^{bcde}	13.7
	28	14.3^{q}	31.0^{a}	13.7
	0	40.6^{fghij}	$28.4^{defghijk}$	13.3
	7	44.7^{a}	$28.5^{defghij}$	13.7
T2	14	42.4^{bcdef}	27.3^{ijklmn}	13.6
	21	39.4^{ijk}	29.9^{abc}	14.1
	28	39.8^{hijk}	30.7^{ab}	14.4
	0	42.0^{cdefg}	29.0^{cdefg}	13.6
	7	39.8^{hijk}	29.3^{cdef}	13.7
T3	14	39.4^{ijk}	$28.4^{defghijk}$	13.4
	21	36.4^{mn}	$28.7^{cdefghi}$	14.3
	28	35.9^{n}	29.2^{cdef}	14.4
	0	41.0^{efghij}	$28.3^{efghijk}$	13.6
	7	42.4^{bcdef}	28.8^{cdefgh}	13.9
T4	14	43.7^{abc}	27.5^{hijklm}	13.6
	21	41.8^{cdefgh}	29.7^{abcd}	13.9
	28	43.5^{abcd}	$28.6^{cdefghi}$	14.4
	0	41.4^{defghi}	27.2^{jklmno}	13.6
	7	40.1^{ghijk}	26.8^{lmno}	13.6
T5	14	39.0^{jkl}	$27.6^{ghijklm}$	13.43
	21	38.3^{klm}	27.3^{ijklmn}	13.9
	28	37.0^{lmn}	28.8^{cdefgh}	14.4
	0	42.3^{bcdefg}	27.0^{klmno}	13.7
	7	44.2^{ab}	$27.7^{ghijklm}$	13.7
T6	14	42.4^{bcdef}	25.9^{o}	13.7
	21	41.3^{efghi}	26.0^{no}	13.9
	28	42.9^{abcde}	26.4^{mno}	14.0
SEM[2]		0.76	0.49	0.20

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6=Beeswax coated, refrigerated temperature stored.

[a-o]Means in a column not sharing a common superscript are significantly different ($P < 0.05$).

[1]Each value represents the mean of seven eggs.

[2]SEM = Pooled standard error mean.

However, yolk indices of all eggs were remained unchanged when the eggs were held from 21 to 28 d. Torrico (2010) reported that generally, the yolk index values decreased with increased storage periods and this reduction was affected by the coating treatment and storage period at 25 °C. Obanu and Mpieri (1984) and Kato (1994) described a progressive weakening of the vitelline membranes and

liquefaction of the yolk caused diffusion of water from the albumen. Akter *et al.* (2014) noticed that the duration and temperatures of storage significantly increased the value of yolk width. However, present study confirmed that the yolk index was not affected by either treatment or storage period beyond 21 d. The increment in yolk width observed in the present study could be due to decline the strength of the vitelline membrane. Similar results were described by Mudannayaka *et al*. (2016) for beeswax coated eggs held at RMT. According to them, the yolk index values of uncoated and coated eggs decreased significantly with increasing storage periods. But reduction progressed at a higher rate in uncoated and Alovera gel coated eggs than beeswax, gelatin and mineral oil coated eggs. Tabidi (2011) reported that reduction rate of yolk index was sharp at room storage.

Table 6: Main effects of preservation technique, storage period and their interactions on yolk quality traits of chicken eggs.

Main effects	Yolk Index (%)	Yolk Ratio (%)	Yolk Colour
Method of preservation			
T1	24.6	29.5	13.6
T2	41.4	29.0	13.8
T3	38.7	28.9	13.9
T4	42.5	28.6	13.9
T5	39.2	27.6	13.8
T6	42.6	26.6	13.8
SEM[2]	0.34	0.22	0.09
Storage period			
0 d	41.3	28.0	13.52[c]
7 d	40.3	28.2	13.69[c]
14 d	38.2	27.9	13.52[c]
21 d	35.4	28.5	13.95[b]
28 d	35.6	29.1	14.24[a]
SEM[2]	0.31	0.20	0.08
Probabilities, p<			
Method of preservation	***	***	NS
Storage period	***	**	***
Method of preservation × Storage period	***	***	NS

T1=Uncoated, room temperature stored (Control); T2=Uncoated, refrigerated temperature stored; T3=Coconut oil coated, room temperature stored; T4=Coconut oil coated, refrigerated temperature stored; T5=Beeswax coated, room temperature stored; T6= Beeswax coated, refrigerated temperature stored.

[a-c]Means in a column not sharing a common superscript are significantly different (P<0.05). [1]Each value represents the mean of seven eggs.

NS, not significant; *P<0.05; **P<0.01; ***P<0.001.[2]SEM=Pooled standard error mean.

***Yolk ratio (%)*:** Yolk ratios of eggs were significantly affected by both the preservation technique (P<0.001) and by the storage period (P<0.01) (Table 5 and 6). A significant interaction (P<0.001) was observed between the preservation technique and the storage period (Table 5 and 6).

On 0 d, exclusive of T3, the yolk ratios were similar between treatments (P>0.05). On 21 d, refrigeration had no significant (P>0.05) effect on the yolk ratios of T2, T4 and T6 as compared to each's counterpart held at RMT. T1 resulted the highest yolk ratio at 28 d of storage period. According to the past research, yolk weight (%) was found to be increased with storage time as the egg weight loss was principally due to a loss in albumen weight (Scott and Silversides, 2000). The results of the present study are an agreement with Akter *et al*. (2014) who described yolk weight as a percentage of egg weight showed significant changes during storage, and increased linearly with the storage time. In contrast, Lall (2014) reports a significant reduction in yolk percentage with increasing storage period. In the present study the highest yolk ratio in 28 d was reported from T1. A similar result was obtained by some other researchers. Lall (2014) described that the eggs stored at RMT showed a significantly higher % of yolk (31.67%). It may be because migration of water from the albumen to the yolk is a function of storage temperatures with a faster migration rate occurring at higher temperatures (Torrico, 2010). Furthermore, the present study showed that no significant (P<0.05) difference existed between storage temperatures on coated or uncoated eggs except between T5 and T6 when the eggs were held for 28 d. However, the findings of some other researchers are conflicting. Akter *et al*. (2014) reported that the rate of increment in yolk weight was significantly affected by the holding temperature and higher than when held at refrigeration (4 °C).

***Yolk colour*:** Yolk colour of the treated eggs assessed under different coating materials and storage temperatures are presented in Table 5 and 6. No significant differences (P>0.05) were observed between preservation techniques for yolk colour. Similarly, no interaction between treatments and storage period had been observed (P>0.05). However, yolk colour (P<0.001) was significantly affected by the period of storage (Table 5). According to the results of the study in the yolk colour increased and was maximum when held for 28 d. The yolk colour from 0 d to 14 d were similar (P>0.05) and increased from 21 to 28 d.

However, conflicting results have been obtained by some other researchers when assessed for yolk colour. Jin *et al.* (2011) reported that a significant change in yolk colour occurred even after two days of storage depending on the storage temperature and the time. According to Jayasena *et al.* (2012), a significant reduction in yolk colour was found between 3 and 5 d after receiving eggs to the market. Present study showed that the yolk colour was only affected and changed with the storage period. This result could be probably due to the membrane degeneration during storage, which may lead water to enter the yolk causing dissolving of the pigment. No recent data were found regarding the relationship between yolk colour and the storage temperature or time.

Evaluation of sensory properties

Evaluation of egg preservation techniques on external sensory properties of table eggs: external shell colour, shell texture, shell odor, broken egg odor and overall

acceptability were accessed between the treatments (Figure 1). Shell colour between the treatments were significantly (P<0.05) affected. T1, T2, T3 and T4 obtained the highest sensory attribute for shell colour whereas T5 and T6 obtained the lowest score for shell colour. Shell texture of the eggs were also different (P<0.05) among treatments. T1, T2, T3 and T4 obtained the highest score for shell texture than T5 and T6. However, shell odor and broken egg odor were not significantly (P>0.05) affected by the treatment. The overall acceptability determines the consumer preference towards the product. Overall acceptability was significantly higher in T3 than other treatments. According to the results T3 showed the highest sensory attributes over other treatments tested.

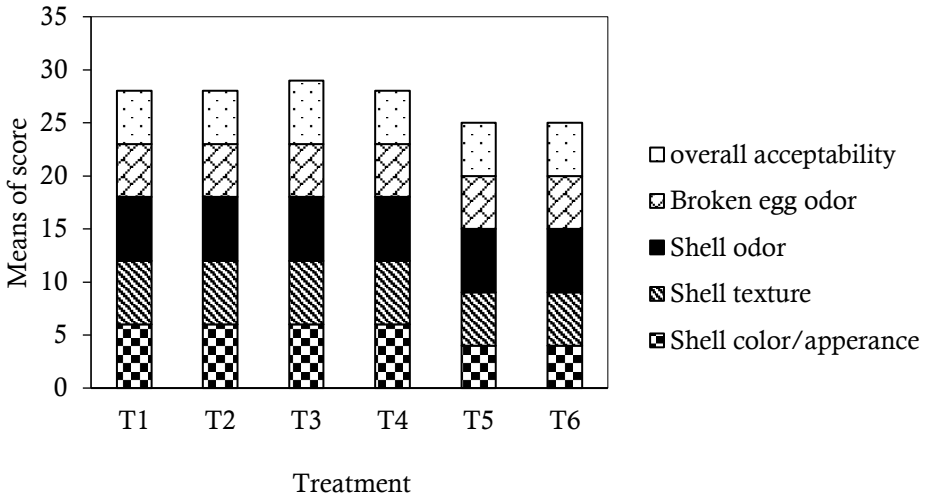

Figure 1: Evaluation of external sensory attributes of table eggs with different coating materials and storage conditions.

The internal sensory properties of treatments held for 14 d were assessed for their colour, smell, taste, albumen texture, overall appearance and general acceptability (Figure 2). The overall appearance was not affected (P>0.05) by the treatment. Also, no significant (P>0.05) differences were observed between treatments for colour, smell and general acceptability. However, the taste of the eggs was significantly (P<0.05) affected by the treatments. T3, T4 and T6 obtained the highest sensory attributes for taste. Albumen texture was affected (P<0.05) by the treatments. T2 obtained the highest sensory attributes for the albumen texture following to T1, T3 and T4. However, beeswax coated eggs (T5 and T6) obtained the lowest score for albumen texture. According to the results of the evaluation of internal sensory attributes, T3 and T4 eggs showed the highest consumer preference for overall sensory properties.

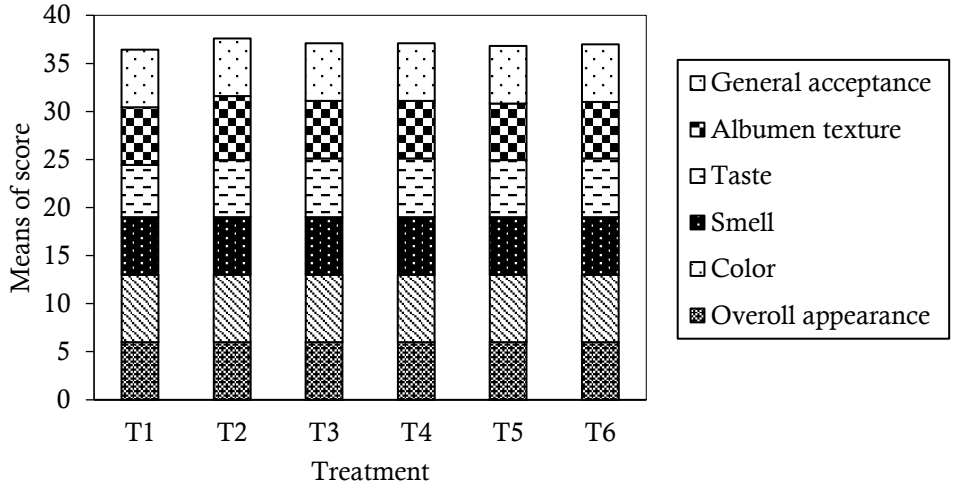

Figure 2: Evaluation of internal sensory attributes of table eggs with different coating materials held for 14-d storage period.

CONCLUSIONS

The present study conclude that egg coating with either beeswax or coconut oil when combined with refrigeration preserves egg quality maximum up to 28 d. Among two coating materials tested, beeswax coated-refrigerated eggs are the best in preserving egg quality. Overall, coconut oil coated eggs stored at room temperature attract panelists the most.

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