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Effect of Sodium Alginate Coating Containing Clove Essential Oil on pH, Cooking Loss, Colour and Sensory Attributes of Refrigerated Rabbit Meat

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ABSTRACT

The present study was undertaken to assess the effect of coating added with clove essential oil on meat quality attributes of rabbit meat. The fresh rabbit meat was divided into 4 treatments viz., C (control)-without coating, T1-alginate coating, T2- alginate coating with 0.2% clove essential oil, and T3- alginate coating with 0.5% clove essential oil. The samples were aerobically packaged in low-density polyethylene (LDPE) packs and stored under refrigeration (4±1ºC) for 7 days. The samples were assessed on day 0 (before keeping the samples in refrigeration), days 1, 3, 5, and 7 for pH, cooking loss, colour profile, and sensory attributes. The alginate coating was observed to significantly ($p<0.05$) increase the pH value of the raw rabbit meat samples. Throughout the storage, the raw C sample recorded significantly ($p<0.05$) lower pH values than those of the raw-treated samples. The coating of the rabbit meat sample did not have any significant effect on the cooking loss except on day 0 of storage. With the advancement of the storage period, the treated samples retained a better colour and sensory attribute. The T3 sample had the highest sensory scores throughout the storage period. Thus, alginate coating added with 0.5% clove essential oil could be used to improve the quality of rabbit meat.

Key words: Edible coating, alginate, eugenol, rabbit meat, meat quality

INTRODUCTION

Rabbits are herbivores and mono-gastric animals with high feed efficiency by converting 20% of feed protein to meat and sustainability potential due to their high fecundity, short gestation period, and cecotrophy. Rabbit meat has an excellent nutritive profile and could be a sustainable source of meat supply (Umaraw et al. 2023; Kumar et al. 2022). Rabbit meat is an excellent source of animal protein (18.6 to 22.4%), essential amino acids and fatty acids, vitamin B_{12}, minerals (1.2-1.6%), and other bioactive compounds with low cholesterol content (Wang et al. 2020; Dalle Zotte and Szendrő 2011). Rabbit meat has a low calorific value (603–899 kJ/100g), with 80% of the energy contributed by protein content (Cullere and Dalla Zotte 2018). It has a lower iron, zinc, and sodium content and a high phosphorus content as compared to other red meat. Rabbit meat has a desirable lipid profile with a higher content of unsaturated fatty acids (60% of all fatty acids, with 27.5% monounsaturated fatty acids and 32.5% polyunsaturated fatty acids) and a n-6/n-3 fatty acid ratio (Dalle Zotte and Szendrő 2011).

Rabbit meat is mainly sold as whole carcasses (due to the small size of the carcass) and in retail cut-up parts. Rabbit is a rich source of high-quality nutrients and moisture, making it prone to spoilage caused by the growth of bacteria and the oxidation of proteins and lipids. Inherently, meat is a poor source of antioxidants and compounds that exert a preservative effect. Further, the oxidation of meat lipids and proteins might also lead to quality deterioration during storage (Awad et al. 2022, 2021). With the increasing awareness of green consumerism and the potential adverse effects of synthetic preservatives, the meat industry is increasingly applying natural preservatives, such as essential oils, to extend the shelf life and maintain the quality of refrigerated meat and meat products. The direct application of essential oils in meat products imparts strong flavour and modifies taste; thus, their direct use in meat is limited. Further, essential oils could also have interactions with other meat ingredients, thus affecting the quality characteristics of meat and meat products (Alexander et al. 2021). Thus, alternatively, the essential oils could be incorporated into the coating. Further, applying suitable technological interventions such as essential oils and edible coatings could extend the shelf-life of meat by inhibiting microbial growth and oxidation of lipids and proteins in meat.

Eugenol is a natural phenolic compound, making it a major component of clove essential oil. It is obtained from the clove plant and other aromatic herbal plants such as basil, pepper, and nutmeg, which have antioxidant and antimicrobial properties. It is used in the meat industry as a natural preservative and to improve flavour (Saricaoglu and Turhan 2019; Pateiro et al. 2021). Eugenol, along with other essential oils, are regarded as 'Generally Recognized as Safe' (GRAS) status and have been approved by the FDA as a food additive (FDA 2015). Edible coatings of proteins and polysaccharides improve the shelf life of food products by protecting against deteriorative changes by forming barriers to solutes, vapours, and gases. Alginic acid, or algin, is an anionic polysaccharide obtained from brown algae, including *Laminaria* and *Ascophyllum* species. It is biodegradable and hydrophilic in nature, and its salt derivates (sodium or calcium alginate), which have limited porosity, are widely used to form coatings around food products. Alginates are linear, unbranched polysaccharides comprising (1→4')-linked β-d-mannuronic acid and α-l-guluronic acid residues (Aramwit 2016). However, when alginates form a film around food products, they increase their shelf life by limiting contact with oxygen, increasing the water barrier, and retaining the flavour of the food (Song et al. 2011). The edible alginate coatings could be carriers of functional ingredients and be biodegradable and biocompatible at the same time.

The application of alginate coatings containing clove essential oils to red meat and poultry has demonstrated a positive effect on maintaining the quality of meat. However, literature related to the application of coatings with functional ingredients to improve the quality attributes of rabbit meat is still scarce. Thus, the present study was undertaken to assess the effect of a sodium alginate coating containing clove essential oil on the quality attributes of refrigerated rabbit meat.

MATERIALS AND METHODS

Rabbit meat and sample preparation

Fresh rabbit meat was purchased from a local firm (Rabbit Jalan Kopi, Lot 7099, Lorong Kopi, Kampung Jenjarom, 42600 Jenjarom, Selangor) and transported (transport duration 40 min) to the Small Animal Slaughterhouse, Animal Science Department, Faculty of Agriculture, Universiti Putra Malaysia, under chilled conditions by using an appropriate ice box. The rabbit meat was manually deboned immediately. The external, visible connective tissue and fat of rabbit meat were removed to ensure the uniformity of the meat chunks. Homogenous cubes (1cm x 1cm x 1cm size) were obtained from rabbit meat and distributed randomly for experimental treatments and analysis. The alginate solution (2% w/v) was prepared as per Alexandre et al. (2021) with suitable modifications. The preparation of the alginate coating solution, incorporation of clove essential oil, and coating method followed are presented in Figure 1.

Sodium-alginate

↓

2% (w/v) alginate solution in sterile distilled water was prepared

↓

Heated using a magnetic stirrer at 75 ºC until totally dissolved/ clarity

↓

Solution was cooled at room temperature

↓

Adding clove essential oil at 0.2% and 0.5% by
adding 0.2g Tween 80/ g clove essential oil

↓

Essential oil was dispersed for 30 min at 40 ºC

↓

Rabbit meat cubes was immersed in an alginate solution
C: Without coating
T1: Coating with alginate solution
T2: Coating with alginate solution added with 0.2% clove essential oil
T3: Coating with alginate solution added with 0.5% clove essential oil

↓

Meat cubes were immersed for 5 min

↓

Drained for 1 min

↓

Dried in hot air oven at 35 ºC for 25 min

↓

Aerobically packed in LDPE (thickness140 gauge) pre-sterilized with
ethyl alcohol

↓

Stored at refrigerated temperature 4 ± 1 ºC and assessed samples on
day 0 (before keeping samples in storage), day 1, 3, 5 and 7

Fig. 1. Preparation of alginate coating solution and treatments

Meat quality attributes

pH determination

The pH of raw and cooked rabbit meat samples during storage was measured using a portable pH meter (Mettler Toledo, AG 8603, Switzerland). Prior to use, the pH meter was calibrated at pH 4.0 and 7.0. Further, 0.5 g of meat sample was crushed and homogenized (Wiggen Hauser D-500 Germany) for 20 s in 10 ml of distilled water. The pH meter probe was then used to measure the pH of the samples. Three replicates were taken from each sample in each treatment.

Cooking loss

Approximately 20g of the sample was sealed in a polyethylene bag and submerged in a water bath preset at 80 ^{o}C until the internal temperature reached 78 ^{o}C (Hayat et al. 2021). The bags were then taken out of the water bath and cooled down for 30 minutes under running water. The bags were opened, and the cooked sample was reweighed again after being gently dabbed dry with paper towels. The cooking loss was measured by noting the difference between the raw and cooked weights of the samples as per the following formula:

Cooking loss (%) = {(Weight of raw rabbit meat sample-weight of cooked meat sample)/weight of raw rabbit meat sample} x 100

Colour profile

Meat colour characteristics (CIE *L**: lightness, *a**: redness, and *b**: yellowness) of raw and cooked rabbit meat samples during storage were measured using the ColourFlex® system by HunterLab with an illuminant D65 as the light source and a 10^{o} standard observer (aperture size of 5 cm). The equipment was calibrated prior to measurement by using white and black reference plates supplied by the manufacturer. Three measurements were taken from each sample in each treatment. The values of chroma (Cab*) and hue (Hab^{o}) were calculated as per the following formula:

$$\text{Chroma} = (a^{*2} + b^{*2})^{1/2}$$

$$\text{Hue} = (\text{Tan}^{-1})\, b^{*}/a^{*}$$

Sensory evaluation

The sensory evaluation of raw rabbit meat samples was carried out by an experienced panel of six in-house panellists comprising laboratory staff and postgraduate students of the Meat Science Laboratory. The panellists graded samples based on appearance, odour, consistency, and texture. The panellists evaluated the sensory analysis of rabbit meat on a 5-point hedonic scale ranging from 1-undesirable, 2-moderately undesirable, 3-good, 4-very good, to 5-excellent (Lytou et al. 2017). Samples were blind-coded and presented to panelists in random orders on a white colour plate with a 3-digit code.

Statistical analysis

All data were analyzed by two-way analysis of variance (ANOVA) using the Statistical Packages for Social Science (SPSS version 27, IBM Ltd., USA). The differences between means were calculated using Duncan's multiple range test (DMRT). The whole set of experiments was replicated three times, and the level of significance (p value) was set at 5% (Snedecor and Cochran 1989).

RESULTS AND DISCUSSION

pH value

The alginate coating was observed to significantly ($p<0.05$) increase the pH value of the raw rabbit meat samples (Table 1). Throughout the storage, the raw C sample recorded significantly ($p<0.05$) lower pH values than those of the raw-treated samples. Within groups, the pH of raw-coated samples (T1, T2, and T3) did not differ significantly ($p>0.05$). The pH value of all raw samples recorded an increasing trend with the advancement of storage days, with the highest pH value recorded on day 7 of storage and the lowest at the beginning of storage. The pH value of raw control samples was recorded significantly ($p<0.05$) lower than the pH value of corresponding raw coated samples recorded on day 7 of refrigerated storage. Similarly, the pH of the raw samples on day 1 was also recorded significantly ($p<0.05$) higher than their corresponding values at the beginning of the experiment (day 0).

The higher pH value of the treated samples throughout the study as compared to control samples could be due to the coating material containing alginate, which had a higher pH value (approx. 7.0). The rabbit meat pH was reported to vary with the muscle type, and the ultimate pH (pHu) of *Biceps femoris* muscle was observed to vary from 5.8 to 5.98 (Hulot and Ouhayoun 1999), which falls within the day 0 value of raw pH samples recorded in the present study. In the present study, the *Biceps femoris* form the majority of the rabbit meat chunks. Further, a higher pH of rabbit carcasses (6.0) was also reported by Rodríguez-Calleja et al. (2004), who attributed it to a higher count of

Gram-positive bacteria and yeast on rabbit carcasses. The increase in the pH of all samples with the advancement of the storage days could be attributed to the increased bacterial degradation of proteins and endogenous enzymes, resulting in the formation of amines, ammonia, and amines (Lan et al. 2016; Rodríguez-Calleja et al. 2005). Similar to the present study, Rodríguez-Calleja et al. (2005) also recorded an increasing pH in the rabbit carcasses stored under chilled conditions (3±1°C) for 8 days. A further rapid increase in the pH of rabbit meat stored under chilled conditions between 2 and 10 days was also reported by Lan et al. (2016).

The pH value of cooked samples recorded an increasing trend with the increasing storage days (Table 1). Similar to raw samples, the cooked control sample had significantly ($p<0.05$) lower pH values on days 1 and 3 as compared to those of cooked-coated samples. The pH of rabbit meat samples increased upon cooking. This increase in pH upon cooking rabbit meat samples could be due to the increased protein denaturation and formation of imidazole in the cooked samples. Kumar et al. (2018) and Verma et al. (2021) also reported similar reports on increased pH values after cooking.

Cooking loss

Cooking loss indicates the water holding capacity of meat under heat and forms a vital meat quality parameter that affects juiciness. The rabbit meat coating did not significantly affect the cooking loss except on day 0 of storage (Figure 2). On day 0, the cooking loss of the control sample was significantly ($p<0.05$) lower than the treated samples. The highest cooking loss value for all samples was recorded on day 7 of storage, and the lowest was recorded on day 0. The cooking loss of control samples increased ($p<0.05$) significantly on day 1 of storage compared to cooking loss measured on day 0.

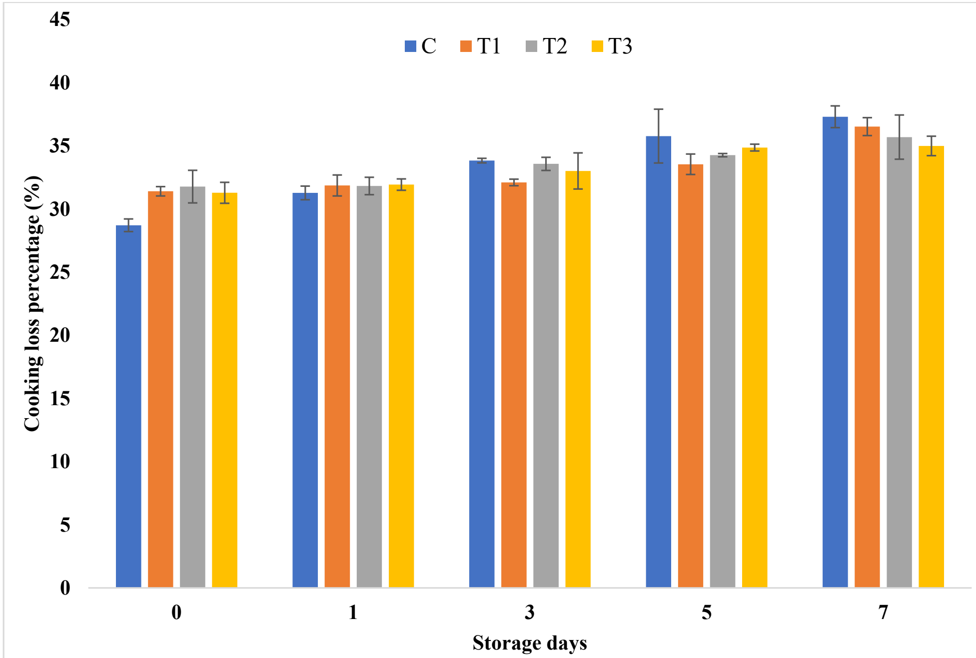
In the present study, the control samples exhibited no significant differences ($p>0.05$) for cooking loss as compared to treated samples from day 3 of storage onwards. On day 7 of storage, the control had the highest cooking loss value, with the T3 sample exhibiting the lowest cooking loss, following the decreasing order as C > T1 > T2 > T3. The lowest value in T3 among treated samples could be due to the antimicrobial effect of clove essential oil. Further, with the increasing level of clove essential oil, the cooking loss followed a non-significantly decreasing trend on day 7. However, similar to the present study, Alexandre et al. (2021) also reported a non-significant change in weight loss in beef samples coated with alginate coating added with basil leaf extract. Vital et al. (2016) also observed a similar trend in beef upon alginate coating incorporated with rosemary and oregano essential oils upon refrigerated storage.

An increase in cooking loss with increasing storage days could be attributed to the increasing degradation of proteins by microbial growth and endogenous enzymes. Further, the higher cooking losses at the end of the storage days could be attributed to proteolysis and myosin denaturation (Xia et al., 2009). The proteolysis of muscle protein resulted in decreased water-holding capacity and higher drip loss, consequently increasing the cooking loss (Olsson et al. 2007). Similar to the present study, an increase in cooking loss with an increasing storage period was also reported in super-chilled and frozen rabbit carcasses by Lan et al. (2016).

Table 1: pH of rabbit meat without and with edible coating during refrigerated storage

Group	Storage days				
	0	1	3	5	7
			Raw meat pH		
C	5.88±0.04^{aA}	6.04±0.02^{bA}	6.11±0.02^{bcA}	6.15±0.01^{cA}	6.27±0.01^{dA}
T1	5.92±0.02^{aB}	6.09±0.02^{bB}	6.17±0.04^{bcB}	6.21±0.03^{cB}	6.33±0.01^{dB}
T2	5.94±0.02^{aB}	6.11±0.01^{bB}	6.20±0.03^{cB}	6.22±0.02^{cB}	6.28±0.02^{dB}
T3	5.95±0.03^{aB}	6.11±0.02^{bB}	6.19±0.01^{cB}	6.23±0.01^{cB}	6.28±0.01^{dB}
			Cooked meat pH		
C	5.92±0.01^{a}	6.11±0.01^{bA}	6.12±0.02^{bA}	6.19±0.01^{c}	6.29±0.02^{c}
T1	5.97±0.03^{a}	6.17±0.02^{bB}	6.18±0.01b^{bB}	6.22±0.02^{bc}	6.30±0.01^{b}
T2	5.95±0.02^{a}	6.20±0.01^{bB}	6.22±0.01b^{bB}	6.21±0.01^{bc}	6.31±0.02^{b}
T3	5.96±0.04^{a}	6.19±0.03^{bB}	6.20±0.03b^{bB}	6.21±0.02^{b}	6.30±0.04^{c}

Values are expressed as mean ±standard error with different superscripts small letters, a, b, c--within a row, and capital letters A, B, C within a column differ significantly ($p<0.05$), Control C- rabbit meat without alginate coating, T1- rabbit meat with alginate coating, T2- rabbit meat with alginate coating added with 0.2% clove essential oil, T3- rabbit meat with alginate coating added with 0.5% clove essential oil, level of significance ($p<0.05$), n=6



Values are expressed as mean ±standard, Control- rabbit meat without alginate coating, T1- rabbit meat with alginate coating, T2- rabbit meat with alginate coating added with 0.2% clove essential oil, T3- rabbit meat with alginate coating added with 0.5% clove essential oil, level of significance ($p<0.05$), n=6

Fig. 2. Cooking loss (%) of rabbit meat without and with alginate coating during refrigerated storage

Colour profile of raw rabbit meat

Colour is an important quality attribute of rabbit meat that affects its appearance and acceptability. All samples' lightness (L^*) values decreased with increasing storage period (Table 2). However, with the advancement of the storage period, the treated samples retained a better L^* value than the control. On day 7 of storage, the L^* value of coated rabbit meat samples was significantly ($p<0.05$) higher as compared to control samples. The L^* value for control was recorded as a significant ($p<0.05$) decrease on day 5 compared to its corresponding value on day 3.

On day 0 of storage, the L^* value of the T1 sample was recorded as significantly lower than the other treatments. The highest L^* value on day 0 was recorded for the T2 and T3 samples. This could be due to the addition of clove essential oil, which increases the lightness of the alginate solution, which otherwise had a darker colour in the absence of clove essential oil, thus imparting the lowest L^* score for T1 samples. On day 1, all samples exhibited comparable ($p>0.05$) L^* values, with the control showing the highest value. This could be due to the alginate coating, which entraps the exudate containing water-soluble proteins and myoglobin from coming out and resulting the proteins to be deposited just beneath the coating layer. This could have resulted in the lower L^* value of these samples. Similar findings of decreasing the L^* value and increasing darkness upon alginate coating in beef during storage under refrigerated conditions were also reported by Alexandre et al. (2021) and Vital et al. (2016).

In general, the redness of rabbit meat in treated samples followed an increasing trend with the increasing storage period, except for T3 on day 0 and day 1 and T1 on day 7 of storage. From day 3 of storage onwards, the redness of coated samples was significantly ($p<0.05$) higher than that of control samples. This could be due to exudates present in coated meat samples, thereby increasing red colouration. Similar findings of increasing redness with the coating of beef samples were also reported by Alexandre et al. (2021). The coating added with clove essential oil helped in maintaining the redness and lighter colour of the rabbit meat during storage. In contrast, upon increasing the storage period, uncoated meat exhibited lower redness and lightness. This characteristic of maintaining red colour and lightness is useful in extending the display life of meat during marketing (Cardoso et al. 2016). The discolouration of stored meat is caused by the conversion of oxymyoglobin to metmyoglobin due to a lack of sufficient oxygen concentration and the action of endogenous enzymes. This causes the natural degradation of meat during storage (Moczkowska et al. 2017). Further, the interaction between lipid oxidation and methemoglobin formation was well established (Faustman et al. 2010; Soladoye et al. 2015). The lower lipid oxidation due to the presence of alginate coating and clove essential oil in T2 and T3 samples could be a factor in the better colour stability of these samples.

The yellowness (b^*) value of alginate-coated samples was recorded as higher than that of the control value from day 1 of storage until the end of storage. This could be attributed to the yellowish-brown colour of the alginate solution. Similar findings of an increasing b^* value upon alginate coating beef during refrigerated storage were also reported by Vital et al. (2016). However, in the present study, a lighter colour of the alginate coating solution was noted upon the incorporation of clove essential oil. This could be the reason for the comparable yellowness values on day 0. However, this effect might be reduced during storage, which could have resulted in a higher b^* value afterwards. Further, the yellow coating could also protect rabbit meat by inhibiting light-induced deterioration.

A higher chroma value (purity and intensity of colour) of alginate-coated samples throughout the storage period was noted as compared to the control. It reflects the vivid colour of coated rabbit meat samples, which may increase consumer acceptance of the alginate-coated rabbit meat samples. Similarly, hue values for alginate-coated samples were better retained than control samples. This indicated the better protection provided by the alginate coating against colour discolouration in rabbit meat samples. On days 5 and 7 of storage, the chroma and hue values were higher in T2 and T3 samples. This could be due to the higher protection against discolouration provided by the clove essential oil in the alginate coating in these samples. Similar findings of higher chroma and hue values in coated meat samples as compared to uncoated samples were also reported by Alexandre et al. (2021), Cardoso et al. (2016), and Vital et al. (2016).

Table 2: Colour profile analysis of raw rabbit meat without and with alginate coating under refrigerated storage

	Storage days				
Group	**0**	**1**	**3**	**5**	**7**
*L**					
C	59.50±0.09^{bcB}	60.50±0.42^{cd}	57.82±1.78^{bA}	53.73±0.14^{aA}	53.41±0.53^{eA}
T1	56.58±0.27^{aA}	58.11±0.74^{b}	57.23±0.44^{b}	56.23±0.80^{aB}	56.90±1.44^{aB}
T2	62.11±0.51^{bC}	58.50±2.17	58.80±0.42^{A}	57.16±0.72^{AB}	58.27±1.19^{B}
T3	61.49±0.70^{cC}	58.17±1.37^{b}	62.26±0.56^{cB}	59.40±0.41^{aAB}	58.03±0.68^{bB}
*a**					
C	9.23±0.15^{aB}	10.42±0.43^{bB}	9.15±0.29^{aA}	11.47±0.10^{cA}	11.97±0.47^{cA}
T1	8.05±0.10^{aA}	10.39±0.96^{bB}	10.57±0.73^{bB}	13.35±0.32^{cB}	11.75±0.40^{bcA}
T2	8.37±0.44^{aA}	11.57±0.25^{bC}	12.56±0.32^{bC}	13.49±0.17^{bB}	13.21±0.25^{bB}
T3	9.44±0.22^{aB}	8.70±0.30^{aAB}	12.22±0.40^{bC}	13.65±0.11^{cB}	13.53±0.39^{bB}
*b**					
C	18.29±0.09^{cC}	11.63±0.42^{aA}	15.73±0.58^{bA}	15.10±0.03^{c}	17.13±1.24^{bc}
T1	14.37±0.17^{aA}	16.78±1.17^{abB}	17.56±0.69^{bB}	16.71±1.07^{ab}	18.79±0.72^{b}
T2	18.32±0.16^{bC}	16.20±0.56^{aB}	19.93±0.08^{bC}	18.61±0.71^{b}	19.02±1.15^{b}
T3	16.77±0.29^{aB}	16.20±0.56^{aB}	20.84±0.37^{cC}	17.14±0.24^{a}	19.68±0.19^{b}
Chroma					
C	16.47±0.13^{aA}	15.64±0.39^{aA}	18.20±0.61^{bA}	21.43±0.08^{c}	20.94±1.18^{c}
T1	20.49±0.14^{cC}	19.75±1.49^{bB}	20.50±0.97^{bB}	21.41±1.03^{b}	22.18±0.71^{b}
T2	21.67±0.26^{bD}	18.27±0.48^{aB}	23.56±0.20^{bC}	23.02±0.49^{b}	23.17±1.65^{b}
T3	19.26±0.15^{aB}	18.41±0.50^{aB}	24.17±0.45^{cC}	21.91±0.24^{b}	22.83±0.07^{b}
Hue					
C	60.73±0.54^{cB}	48.13±1.66^{aA}	59.76±0.68^{c}	51.10±1.15^{aA}	54.71±1.76^{bA}
T1	63.23±0.29^{dC}	58.47±0.74^{bcB}	59.14±0.79^{bc}	51.46±0.29^{aAB}	55.55±1.00^{abA}
T2	57.76±0.36^{bA}	62.58±1.66^{cB}	57.80±0.64^{b}	53.92±1.36^{aB}	57.91±1.02^{bAB}
T3	60.58±0.98^{bB}	61.65±1.26^{bB}	59.63±0.74^{b}	57.64±0.19^{bcC}	59.65±1.07^{bB}

Values are expressed as mean ± standard error with different superscripts small letters, a, b, c--within a row and capital letters A, B, C within a column differ significantly ($p<0.05$), Control C- rabbit meat without alginate coating, T1- rabbit meat with alginate coating, T2- rabbit meat with alginate coating added with 0.2% clove essential oil, T3- rabbit meat with alginate coating added with 0.5% clove essential oil, L^* = Lightness, a^* = Redness, b^* = Yellowness, Chroma = (a*2 + b*2) ½, Hue = (Tan-1) b*/a*, level of significance ($p<0.05$), n=6

Colour profile of cooked rabbit meat

The colour of coated cooked rabbit meat better retained the L^* and redness as observed on the last date of storage (Table 3). On days 5 and 7 of storage, the highest L^* was noticed in the T3 samples as compared to the other samples. Further, L^* value of the T3 sample on days 5 and 7 was significantly ($p<0.05$) higher than that of the T2 sample. This could be due to the higher concentration of clove essential oil having a high concentration of the active ingredient eugenol, thereby exerting a higher antioxidant and antimicrobial (preservative) effect in meat (Sharma et al. 2017). This improved the oxidative stability and inhibited microbial degradation, thereby improving the colour stability of the meat samples. However, in the present study, a slight increase in the L^* value was noticed upon cooking rabbit meat samples. A similar increase in the lightness value upon cooking was also recorded in emu meat (Nithyalakshmi and Preetha 2015) and in beef (Yancey et al. 2011). Similar to the L^* value, the redness value of the cooked sample was also decreased upon cooking. However, this trend mostly depends on the time-temperature combinations and the cooking process, and a higher cooking temperature could cause denaturation of myoglobin (Yancey et al. 2011). In the present study, the cooking of rabbit meat could have caused the denaturation of myoglobin, which could be the reason for the lower redness score of the cooked rabbit meat samples.

Table 3: Colour profile analysis of cooked rabbit meat without and with alginate coating under refrigerated storage

Group	Storage days				
	0	**1**	**3**	**5**	**7**
*L**					
C	64.34±0.14^{aA}	67.09±1.20^{bC}	68.42±0.84^{bC}	63.03±0.44^{abA}	64.89±0.33^{aB}
T1	68.15±0.56^{cC}	59.65±1.72^{aA}	64.88±0.48^{bB}	67.90±1.14^{cB}	63.17±0.35^{bA}
T2	65.94±0.15^{cB}	63.52±0.75^{bB}	62.23±0.18^{aA}	66.17±0.59^{cB}	64.88±0.08^{bB}
T3	65.73±0.44^{bB}	62.75±0.93^{aAB}	65.04±0.68^{bB}	71.82±0.13^{cC}	67.98±0.09^{dC}
*a**					
C	2.65±0.02^{cB}	1.39±0.20^{abA}	1.23±0.20^{aA}	1.74±0.04^{bA}	2.33±0.12^{cA}
T1	2.47±0.11^{B}	2.83±0.35^{B}	2.32±0.16^{B}	2.60±0.08^{B}	2.55±0.05^{A}
T2	2.06±0.09^{aA}	2.48±0.15^{abB}	2.80±0.08^{bC}	2.53±0.20^{bB}	2.46±0.17^{abA}
T3	2.49±0.05^{abB}	2.41±0.10^{aB}	2.58±0.05^{bcBC}	2.71±0.01^{cB}	3.05±0.02^{dB}
*b**					
C	14.17±0.12^{cB}	12.33±0.32^{bA}	11.04±0.52^{aA}	13.27±0.12^{bcB}	14.02±0.44^{cB}
T1	14.00±0.18^{cB}	14.20±0.38^{cB}	13.39±0.15^{bcB}	12.38±0.49^{aA}	12.81±0.12^{abA}
T2	12.75±0.14^{aA}	13.46±0.42^{abAB}	13.85±0.21^{bcB}	14.18±0.16^{bcC}	14.36±0.36^{cB}
T3	12.50±0.26^{aA}	12.58±0.51^{abA}	13.37±0.23^{abB}	13.43±0.17^{bBC}	14.47±0.06^{cB}
Chroma					
C	14.42±0.12^{cB}	12.41±0.33^{bA}	11.11±0.54^{aA}	13.38±0.12^{bcAB}	14.21±0.46^{cB}
T1	14.22±0.19^{bB}	14.50±0.43^{bB}	13.59±0.17^{abB}	12.66±0.46^{aA}	13.06±0.13^{aA}
T2	12.91±0.15^{aA}	13.68±0.44^{abAB}	14.13±0.22^{bB}	14.41±0.19^{bC}	14.57±0.38^{bB}
T3	12.75±0.25^{aA}	12.80±0.52^{aA}	13.62±0.22^{abB}	13.70±0.17^{bBC}	14.78±0.06^{cB}
Hue					
C	79.40±0.04^{aAB}	83.67±0.79^{bB}	83.83±0.78^{bC}	78.58±0.09^{bAB}	80.61±0.21^{aB}
T1	80.02±0.34^{BC}	78.88±1.15^{A}	80.21±0.55^{B}	77.98±0.81^{A}	78.75±0.14^{A}
T2	80.82±0.31^{bC}	79.59±0.35^{abA}	78.57±0.18^{aA}	79.92±0.66^{bB}	80.35±0.41^{bB}
T3	78.72±0.41^{abA}	79.16±0.31^{abA}	79.06±0.25^{bAB}	82.54±0.23^{bC}	78.10±0.13^{aA}

Values are expressed as mean ± standard error with different superscripts small letters, a, b, c--within a row and capital letters A, B, C within a column differ significantly ($p<0.05$), Control C- rabbit meat without alginate coating, T1- rabbit meat with alginate coating, T2- rabbit meat with alginate coating added with 0.2% clove essential oil, T3- rabbit meat with alginate coating added with 0.5% clove essential oil, L* = Lightness, a* = Redness, b* = Yellowness, Chroma = (a*2 + b*2) ½, Hue = (Tan-1) b*/a*, level of significance ($p<0.05$), n=6

Sensory analysis

Sensory attributes are important in determining consumer acceptance and marketing of meat products. The sensory attributes followed a decreasing trend with the increasing storage days (Table 4). The appearance scores of control and treatment samples were recorded as comparable on days 0 and 1 of storage; after that, the treatment samples exhibited a significantly ($p<0.05$) higher value than the control samples. This could be due to better colour retention in the treated samples caused by lower microbial degradation and enzymatic activities. The colour profile of the raw rabbit meat is also in line with this trend. The appearance score of the raw control samples significantly ($p<0.05$) decreased with the advancement of the storage period, thereby exhibiting the lowest value on day 7 and the highest value on day 0. Further, T1 and T2 samples also followed a similar trend in appearance score upon increasing storage period. The appearance score of T3 samples on day 0 and day 1 was recorded as comparable ($p > 0.05$). This could be due to the higher concentration of clove essential oil (0.5%) in the alginate coating of these samples. Similar findings of a better appearance score awarded to alginate-coated lamb meat at the end of the storage days (total storage duration: 7 days) were also reported by Matiacevich et al. (2015).

At the start of the experiment, the odour of all samples did not vary significantly. The same trend also continued on day 1 of storage; after that, the odour score of coated samples was significantly ($p<0.05$) higher than that of the control. On day 5 onwards, a rapid fall in the odour score was observed by the panelists. On day 7 of storage, the panelists noted a slightly unpleasant odour in control samples, whereas no such unpleasant odour was noticed in coated samples. Among the coated samples, the T3 samples had the highest odour value on day 7. Further, the panelists noted a smooth odour of clove essential oil in the T2 and T3 samples; however, on the last day of storage, this odour of clove essential oil could only be perceived in the T3 sample.

The consistency and texture of the control and coated samples remained comparable and did not vary significantly among groups until day 3 of refrigerated storage. Thereafter, the control samples recorded a rapid decline in the consistency and texture score in the control sample, leading to a significantly ($p<0.05$) lower value than those of the coated samples. consistency and texture score of all samples on day 1 and day 0 were recorded as comparable ($p > 0.05$).

The unpleasant odour in the rabbit meat after 6 days of refrigeration (4 °C) was also reported by Lan et al. (2016). The authors (Lan et al. 2016) attributed it to the increased microbial activity leading to proteolysis and the formation of total volatile basic nitrogen (TVB-N) in rabbit meat. A TVB-N value of more than 15 mg/100 g in rabbit meat is considered an acceptable limit, and values above that value result in a marked deterioration in odour and other sensory attributes (Lan et al. 2016). Similarly, in carp, Mi et al. (2013)

Table 4: Sensory profileof raw rabbit meat without and with alginate coating under refrigerated storage

Group	Storage days				
	0	1	3	5	7
Appearance					
C	$4.85{\pm}0.12^{e}$	$4.71{\pm}0.08^{d}$	$4.38{\pm}0.09^{cA}$	$3.92{\pm}0.08^{bA}$	$3.72{\pm}0.04^{aA}$
T1	$4.84{\pm}0.07^{e}$	$4.72{\pm}0.05^{d}$	$4.45{\pm}0.03^{cB}$	$4.01{\pm}0.11^{bAB}$	$4.04{\pm}0.05^{aB}$
T2	$4.84{\pm}0.05^{e}$	$4.78{\pm}0.07^{d}$	$4.59{\pm}0.07^{cB}$	$4.14{\pm}0.07^{bB}$	$4.05{\pm}0.04^{aB}$
T3	$4.85{\pm}0.06^{d}$	$4.82{\pm}0.05^{d}$	$4.58{\pm}0.06^{cB}$	$4.13{\pm}0.09^{bB}$	$4.08{\pm}0.03^{aB}$
Odour					
C	$4.84{\pm}0.07^{d}$	$4.76{\pm}0.09^{d}$	$4.11{\pm}0.04^{cA}$	$3.72{\pm}0.13^{bA}$	$2.85{\pm}0.11^{aA}$
T1	$4.82{\pm}0.06^{d}$	$4.80{\pm}0.07^{d}$	$4.59{\pm}0.08^{cB}$	$4.06{\pm}0.05^{bB}$	$3.51{\pm}0.09^{aB}$
T2	$4.82{\pm}0.03^{e}$	$4.81{\pm}0.04^{d}$	$4.64{\pm}0.07^{cC}$	$4.12{\pm}0.04^{bB}$	$3.94{\pm}0.06^{aC}$
T3	$4.83{\pm}0.03^{d}$	$4.82{\pm}0.03^{d}$	$4.67{\pm}0.06^{cC}$	$4.21{\pm}0.06^{bB}$	$4.01{\pm}0.05^{aC}$
Consistency and texture					
C	$4.83{\pm}0.08^{d}$	$4.69{\pm}0.07^{d}$	$4.25{\pm}0.05^{c}$	$3.91{\pm}0.06^{bA}$	$3.14{\pm}0.04^{aA}$
T1	$4.81{\pm}0.05^{d}$	$4.75{\pm}0.09^{d}$	$4.46{\pm}0.08^{c}$	$4.12{\pm}0.08^{bB}$	$3.83{\pm}0.06^{aB}$
T2	$4.80{\pm}0.07^{d}$	$4.78{\pm}0.04^{d}$	$4.55{\pm}0.05^{c}$	$4.16{\pm}0.04^{bB}$	$4.01{\pm}0.04^{aB}$
T3	$4.82{\pm}0.05^{d}$	$4.81{\pm}0.04^{d}$	$4.57{\pm}0.05^{c}$	$4.19{\pm}0.06^{bB}$	$4.04{\pm}0.06^{aB}$

Values are expressed as mean ± standard error with different superscripts small letters, a, b, c--within a row and capital letters A, B, C within column differ significantly ($p<0.05$), Control- rabbit meat without alginate coating, T1- rabbit meat with alginate coating, T2- rabbit meat with alginate coating added with 0.2% clove essential oil, T3- rabbit meat with alginate coating added with 0.5% clove essential oil, level of significance ($p<0.05$), n=21 by using 5 point hedonic scale noted higher TVB-N, leading to off-odour after 6 days of storage at 3 °C. Further, Rodríguez-Calleja et al. (2005), based on the microbial count (maximum permissible limit of 8 log CFU/g), also reported the mean shelf-life of rabbit carcasses up to 6.8 days. However, Rodríguez-Calleja et al. (2005) also noted that the higher pH and lower extract release volume in rabbit meat resulted in the emanation of a strong putrid odour from rabbit meat after 4 days of storage.

CONCLUSION

The edible alginate coating was recorded to affect rabbit meat's pH, cooking loss, colour, and sensory profile. The alginate coating was observed to significantly ($p<0.05$) increase the pH value of the raw rabbit meat samples. Throughout the storage, the raw C sample recorded significantly ($p<0.05$) lower pH values than those of the raw-treated samples. With the advancement of the storage period, the treated samples retained a better colour and sensory attribute. The T3 sample had the highest sensory scores throughout the storage period. Thus, alginate coating added with 0.5% clove essential oil could be used to improve the quality of rabbit meat.

COMPETING INTEREST

The authors do not have any competing interests among themselves or others related to this research work.

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ETHICAL STATEMENT

Not applicable

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