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EFFECT OF ALGINATE COATING ON THE QUALITY OF FRESH-CUT MUSKMELON FRUIT (*CUCUMIS MELO* L.)

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Abstract: The main purpose of this study is to evaluate the changes in the quality of fresh-cut muskmelon fruit using alginate coating as the edible film at 4–6ºC. A set of experiments was designed to determine the effect of various concentrations of alginate (1%, 1.5%, 2%, and 2.5%, w/v), glycerol 1.5% (v/v), and $CaCl_2$ 2% (w/v) on the quality of fresh-cut muskmelon fruit. Changes in fruit weight loss, reducing sugar, total soluble solids, vitamin C, acidity, and color parameters were recorded during the storage time. Sensory testing and microbiological analysis were evaluated in the last storage period. Uncoated fresh-cut muskmelon fruit stored at 4–6ºC served as controls. Application of an edible coating composed of an alginate concentration of 2% (w/v), glycerol 1.5% (v/v), and $CaCl_2$ 2% (w/v) helps extend the shelf-life of fresh-cut muskmelon fruit (up to 9 days).

Keywords: Alginate, Cucumis melo L., edible coating, fresh-cut, preservation.

INTRODUCTION

Fruit is one of the foods that provide lots of vitamins that play an important role in health. Among them, *Cucumis melo* L. has a high nutritional value, a high sugar content, and is a rich source of phytonutrients (Lester, 2008), especially vitamins A, B_6, and C. This plant belongs to the Reticulatus group, its common name is muskmelon and it is a member of the Cucurbitaceae family (Bailey, 1976). In Vietnam, customer demand for this fruit has increased rapidly in recent years. Hence, the price of this fruit is very high, approximately ~2.5 USD/kg. However, the preservation of this fresh-cut fruit is quite difficult due to different causes such as weight loss, polyphenol oxidase activity, microorganisms, and respiration of fruit. In their raw state, and even when minimally processed, these fresh-cut products remain in a fresh state and ready to eat or cook. This is quite convenient and their flavor maintains a freshness (Garrett, 2002). Therefore, the preservation of fresh-cut muskmelon is quite necessary in the current conditions.

Nowadays, there are many methods for preserving fresh-cut fruit; for instance, using a multilayered antimicrobial edible coating for shelf-life extension of fresh-cut cantaloupe (Martiñon *et al.*, 2014), using chitosan coating incorporated with rosemary extracts to preserve fresh-cut pears (Xiao *et al.*, 2010) and changes of the various shapes to preserve fresh-cut papaya (Morais *et al.*, 2010), etc. In general, edible film is widely used in fruit storage technology, especially fresh-cut fruit. This method can be combined with other factors such as low temperature, modified atmosphere packaging, controlled atmosphere (Bico *et al.*, 2009), antioxidants (Xiao *et al.*, 2010), oil (Azarakhsh *et al.*, 2012), and essential oil (Yuan *et al.*, 2019). Consequently, choosing the suitable storage method is very important and also depends on the fruit and actual conditions. In previous studies, we found that there are not any studies that have recorded the effect of an alginate base coating on the quality of fresh-cut muskmelon. Thus, the objective of this work was to evaluate the fresh-like quality of fresh-cut muskmelon, by using alginate as an edible coating and to study the effects on physicochemical and microbiological qualities of that fresh-cut produce.

MATERIALS AND METHODS

Plant materials and experimental design

Muskmelon (*Cucumis melon* L.) fruits were harvested from Hoang Xuan farm in Trang Bang district, Tay Ninh province, Vietnam. Fruits were picked at the commercial maturity stage (with more green bark than white veins) and they were uniform in size (1–1.2 kg/unit, with a diameter of 18–20 cm), free of physical damage, and fungal infection. Total soluble solids content obtained was 8–10º Brix. Fruits were brought to the laboratory immediately after harvest. The muskmelons were cut into many pieces approximately 3×3×2 cm in size. Next, five homogeneous lots of ten pieces each were performed at random, one lot was used to determine the fruit properties as the control samples and the rest were split into four groups for the following treatments in triplicate: 1%, 1.5%, 2%, and 2.5% (w/v) alginate coating.

Alginate was purchased from Haihang Industry Co. (China) and all other chemicals were of analytical reagent grade. The alginate solution was prepared according to Oms-Oliu *et al.* (2008b) at different concentrations 1%, 1.5%, 2%, and 2.5% (w/v). They were placed in hot water (70°C) until completely dissolved. After cooling to room temperature, glycerol was added as a plasticizer to 1.5 g/100 g alginate. The fresh-cut muskmelon pieces were dipped in the alginate solution for 2 min, drained for 1 min and after that, they were dipped in 2% (w/v) $CaCl_2$ solution for 2 min. Then, they were stored in a sealed plastic box at 4–6°C (10 pieces/box). All samples were analyzed after 3 days at room temperature.

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Fruit quality parameters

Weight loss

Weight loss was determined in each lot by percentage of weight loss with respect to day 0.

Color parameters

The color parameters of the fresh melon were determined by the Minolta CR-400 colorimeter (Japan) and expressed as L^* (brightness), a^* (from green to red), and b^* (from blue to yellow).

Total soluble solids content

The sample was crushed, then collected to analyze total soluble solids content using a portable refractometer (ATC, China).

Reducing sugar

Reducing sugar content was determined by the 3,5-dinitrosalicyclic acid (DNS) method with slight modifications based on the study by Miller (1959). This is a redox reaction between the DNS and the reducing sugars in the sample. The DNS (yellow color) is reduced to 3-amino-5-nitrosalicylic acid (red-brown color) which can be quantified by spectrophotometry at 530 nm.

The acidity content

The titratable acidity (TA) content was analyzed by potentiometric titration with 0.1 N sodium hydroxide (NaOH), using 10 g fruit ground with 150 mL distilled water and heated at 80°C for 15 minutes. Then, the mixture was filtrated and made up to 250 mL. After that, the solution was titrated by 0.1 N NaOH with 3 drops of phenolphthalein (0.1%, w/v) as an indicator. The volume of NaOH was recorded and results are expressed as grams of citric acid equivalent per 100 g fresh weight (FW).

Vitamin C content

Approximately 10 g of fresh-cut muskmelon was ground in 20 mL HCl (2%). The mixture was filtrated and made up to 100 mL. Then, 10 mL of this solution was transferred to a flask and 3 drops of 1% starch paste were added. The solution obtained was titrated by 0.005 N I_2 solution until a light blue color appears for 20 seconds. The volume of I_2 was recorded and used to quantify vitamin C content. Results are expressed as milligrams of ascorbic acid per 100 g of FW.

Sensory methods.

The 60 non-trained panelists evaluated the fresh-cut muskmelon by color, odor, taste, texture, and overall acceptability, using 9-point hedonic scales from 1 (dislike extremely) to 9 (like extremely) (Meilgaard *et al.*, 2007) in the last storage period.

Microbiological analysis

The aerobic plate count, *Escherichia coli*, *Salmonella* spp., total yeast and mold count were determined according to ISO 4833-1 (2013), ISO 16649-1 (2001), ISO 6579-1 (2017), and ISO 21527-2 (2008), respectively.

Data analysis

The experimental data were analyzed using the one-way analysis of variance (ANOVA) method and significant differences among the means from triplicate analyses at $p<0.05$ were determined by Fisher's least significant difference (LSD) procedure using Statgraphics software (Centurion XV). The values obtained were expressed in the form of a mean±standard deviation (SD).

RESULTS AND DISCUSSIONS

Effect of alginate concentrations on weight loss

During the storage time, there is a significant difference in weight loss among alginate concentrations ($p<0.05$). The weight loss of all samples insignificantly changed on the 3rd day while there were some significant differences on 6th and 9th day. The weight loss of all increased dramatically during storage time. Among the samples, the lowest weight loss value (1.3% after 9 days of cold storage) was that of the alginate concentration of 2%. This is lower than the weight loss of the control sample at the same time (1.92%) (Fig. 1). The main cause of weight loss is water loss. The skinless tissue of fresh-cut muskmelon is exposed to the ambient environment with lower relative humidity. This causes substantial weight loss. In addition, other components were released in the respiration process, for instance, gaseous products, aroma, or flavor. These also caused weight loss but the change was not significant (Olivas *et al.*, 2005). This showed that alginate coatings on fresh-cut muskmelon work effectively as water vapor barriers during the entire storage period. Olivas *et al.* (2007) believed that edible coating could reduce water loss producing high relative humidity at the surface of fresh-cut muskmelon, thus decreasing the gradient to the exterior. Similar previous studies indicated that alginate coating used on fresh-cut papaya was effective in reducing water loss when phenolic compounds from *Polygonum multiflorum* Thunb. root extract was applied in the coating formulation (Quoc *et al.*, 2016), or the combination of alginate and sunflower oil can prevent water loss of fresh-cut pineapple (Adzahan *et al.*, 2012), and the combination of alginate and acetyl monoglyceride can prevent water loss of fresh-cut apple (Olivas *et al.*, 2007).

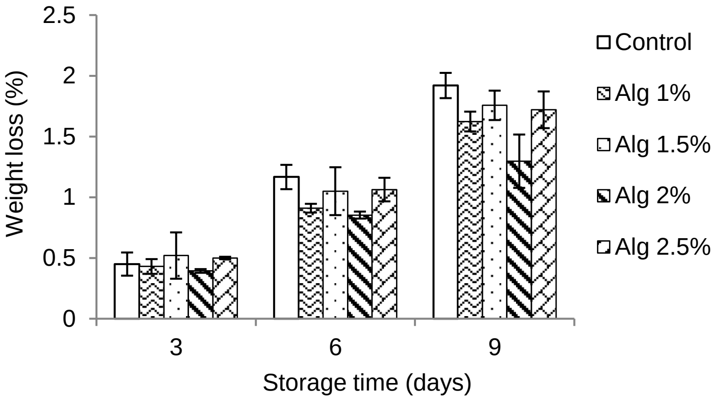

Fig. 1 Effect of alginate concentrations on weight loss of fresh-cut muskmelon.

Effect of alginate concentrations on reducing sugar content

Based on Fig. 2, there is no significant difference in samples between the storage time and alginate concentrations ($p>0.05$). The reducing sugar content at day 0 initially reaches approximately from 7.48% to 8.76% while total soluble solids content is from 8.17% to 9.93%. Both of them decrease steadily during the storage time. On the 9th day, the reducing sugar content and total soluble solids content of all samples fluctuate from 6.43% to 7.36% and from 6.67% to 8.07%, respectively (Fig. 2 and 3).

Fruits tend to change the amount of reducing sugar in different ways during storage time; for instance, the reducing sugar content of fresh-cut muskmelon in this case decreases whereas that of fresh-cut papaya increased gradually after 6 days of cold storage (Quoc *et al.*, 2016). This may be due to the fact that the starch content of papaya is higher than that of muskmelon and enzymes in the material hydrolyzed the starch into sugar. Hence, the sugar content of fresh-cut papaya increased during storage time. However, in another case, the sugar content of fresh-cut Gala apples remained constant during the storage time at 1°C (Bett *et al.*, 2001). Sugars are commonly thought to be synonymous with soluble solids. However, the real ratio of soluble solids of sugars analyzed depends on the fruit or vegetable.

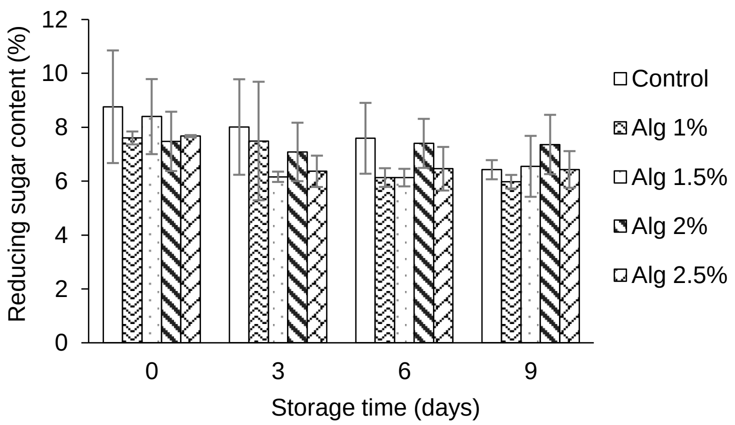

Fig. 2 Effect of alginate concentrations on total reducing sugar content of fresh-cut muskmelon.

Fig. 3 shows that the soluble solids content of the initial material is similar to that of fresh-cut cantaloupe in Texas (8.5%–10%) (Martiñon *et al.*, 2014). Decreasing in the soluble solids content of material during storage time is in agreement with that of 17 Western cantaloupe varieties (Cantwell *et al.*, 1997), cut peaches (Mencarelli *et al.*, 1998), etc. In general, the soluble solids content or sugar content is positively correlated with desirable flavor quality. Higher soluble solids content indicates that vegetables and fruits have a certain degree of sweetness. In this study, the changing trend of soluble solids content is quite similar to the trend of reducing sugar.

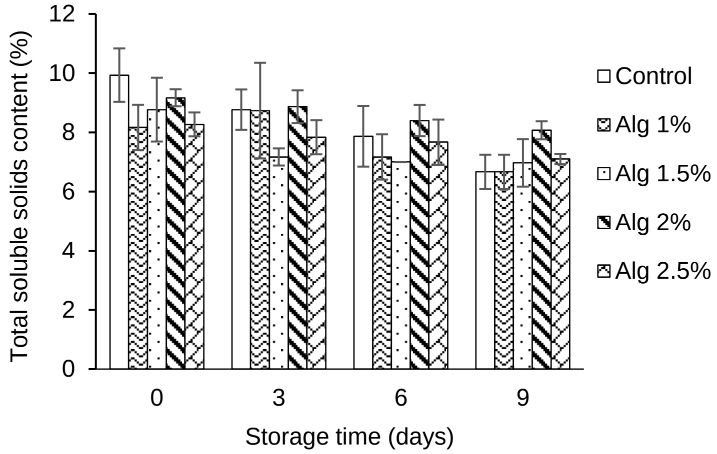

Fig. 3 Effect of alginate concentrations on total soluble solids content of fresh-cut muskmelon.

Effect of alginate concentrations on acid content

Based on Fig. 4, the results obtained have a significant difference between some timelines ($p<0.05$). At day 0, the acid content in the samples was approximately 0.1% to 0.16%. This is lower than that of other melon varieties, for instance, Piel de Sapo melon (0.276%) (Oms-Oliu *et al.*, 2008a). During the storage time, the acid content of all samples (except the control sample) increases slightly until the 9th day. Changes in the acid content of fruit are quite complex, they depend on the fruit or vegetable. This change is similar to that of fresh-cut papaya (Quoc *et al.*, 2016), whereas that of fresh-cut Gala apples and of oranges decreased during the storage time (Olivas *et al.*, 2007; Rocha *et al.*, 1995). The main organic acids noted for most fruits are malic, citric, tartaric, succinic, and quinic acids. Changes in acid content also depend on the cultivar. These organic acids are also substrates for many enzyme-catalyzed reactions during aerobic respiration in plant cells; this leads to the fruits tasting relatively sweeter (Maftoonazad *et al.*, 2008).

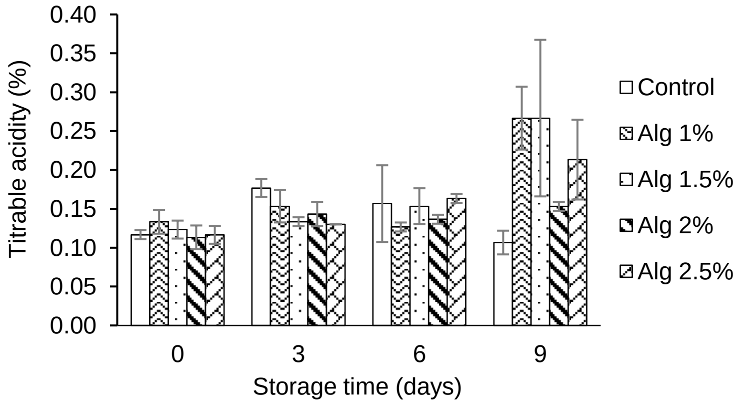

Fig. 4 Effect of alginate concentrations on the acid content of fresh-cut muskmelon.

Effect of alginate concentrations on vitamin C content

Fig. 5 shows that the initial material has a relatively high vitamin C content (approximately 100 mg/100 g FW) compared with other materials, for instance, fresh-cut pineapples (nearly 7 mg/100 g FW) (Gonzalez-Aguilar *et al.*, 2005), fresh-cut pears (4.2–4.9 mg/100 g FW) (Xiao *et al.*, 2010), etc. Therefore, muskmelon is a fruit that provides a rich source of vitamin C for the body. Thus, it is necessary to preserve and maintain the vitamin C content in fresh-cut melon.

In general, vitamin C content of the control sample tends to decrease from 100 mg/100 g FW to 65.67 mg/100 g during the storage time, while the rest of the alginate coating sample fluctuates from 72.33 to 83.33 mg/100 g FW on the 9th day. Among the samples, the alginate coating of 2% maintains the best vitamin C content (83.33 mg/100 g) (Fig. 5). This shows that the alginate coating has a positive effect on the vitamin C content of fresh-cut muskmelon. The decrease in vitamin C content in these results is similar with other fruits during the storage time, for instance, fresh-cut Piel de Sapo melon (Oms-Oliu *et al.*, 2008a), fresh-cut pineapples (Figueiredo *et al.*, 2003), etc. Vitamin C in fresh-cut fruit exposed to the ambient atmosphere may be converted into dehydroascorbic acid and further decomposed into 2,3-diketogulonic acid during storage time.

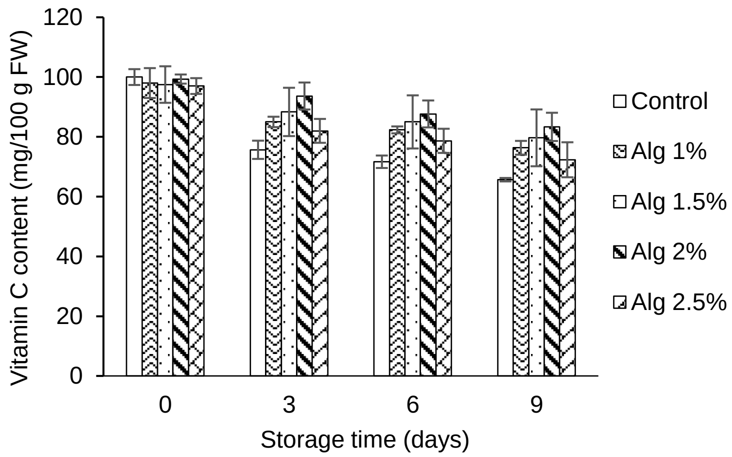

Fig. 5 Effect of alginate concentrations on the vitamin C content of fresh-cut muskmelon.

Effect of alginate concentrations on color parameters

Color is one of the most important factors determining consumer acceptance of the quality of the fresh-cut fruit. It indicates the freshness, the deterioration of fruit or contamination of the product, etc. Table 1 shows that the L^*, a^*, and b^* values are not significantly different between control and all treated samples ($p>0.05$) (Table 1). However, all these values tend to decrease during storage time. In the control sample, L^* values drop from 62.52 to 55.66, a^* values drop from 13.55 to 11.96 and b^* values drop from 34.73 to 29.85, while in treated samples, L^* values drop from 62.89 to 56.96, a^* values drop from 14.74 to 10.72 and b^* values drop from 35.07 to 27.33. This proved that the alginate coating does not significantly affect the color of the product. These results are similar to those of the study by Chong *et al.* (2015), who preserved fresh-cut honeydew melon with a combination of chitosan and calcium chloride at 7°C for 13 days. For the fresh-cut fruits or vegetables, the tissue is broken and the polyphenol oxidase (PPO) is released and exposed to oxygen from the ambient atmosphere, causing discoloration. However, this phenomenon may not appear clearly for fresh-cut muskmelon.

Table 1

Effect of alginate concentrations on color parameters of fresh-cut muskmelon

Storage time (days)	Alginate concentration (%)				
	Control	1	1.5	2	2.5
	L^*				
0	62.52±2.88^{Ba}	61.62±1.57^{Ba}	61.04±3.73^{Aa}	62.89±0.78^{Aa}	61.63±3.67^{Aa}
3	61.17±1.35^{ABa}	61.34±1.44^{Ba}	61.70±0.89^{Aa}	62.79±3.56^{Aa}	61.50±2.66^{Aa}
6	59.41±0.94^{ABa}	60.69±0.68^{ABa}	61.13±4.38^{Aa}	63.57±3.23^{Aa}	62.55±5.91^{Aa}
9	55.66±5.22^{Aa}	56.95±3.30^{Aa}	59.32±3.96^{Aa}	61.61±1.68^{Aa}	59.61±8.04^{Aa}
	a^*				
0	13.55±1.16^{Aa}	14.08±0.74^{Ba}	14.77±0.61^{Ba}	14.74±1.10^{Aa}	13.54±2.52^{Aa}
3	13.62±0.54^{Aab}	13.82±0.52^{ABab}	14.55±0.51^{Bb}	14.48±0.76^{Ab}	12.58±1.43^{Aa}
6	12.36±1.12^{Aa}	12.98±1.11^{ABa}	13.90±0.82^{Ba}	13.84±1.23^{Aa}	12.42±0.70^{Aa}
9	11.96±1.95^{Aa}	10.72±3.12^{Aa}	13.22±3.49^{Aa}	12.52±1.37^{Aa}	11.29±4.29^{Aa}
	b^*				
0	34.73±2.18^{Ba}	34.22±1.53^{Ba}	35.07±0.97^{Aa}	32.14±1.41^{Aa}	33.09±3.60^{Aa}
3	34.00±0.63^{ABa}	33.76±1.29^{Ba}	33.81±0.73^{Aa}	33.30±0.57^{Aa}	30.63±2.60^{Ab}
6	33.75±2.77^{ABa}	32.11±0.98^{ABa}	33.62±1.22^{Aa}	32.28±1.27^{Aa}	30.83±2.39^{Aa}
9	29.85±3.68^{Aa}	27.33±5.56^{Aa}	32.81±3.29^{Aa}	31.65±0.96^{Aa}	29.19±3.42^{Aa}

Different superscript lower-case letters in the same row denote significant differences ($p<0.05$).
Different superscript capital letters in the same column denote significant differences ($p<0.05$).

Microbiological analysis and sensory attributes of products

During storage time, alginate coating with the concentration of 2% has many advantages more than other concentrations because the decrease in weight loss, sugar content, titrable acidity, and vitamin C content change insignificantly. Therefore, the sample at this concentration was selected to evaluate sensory and microbiological analysis compared with the control sample after 9 days of storage.

Table 2

Sensory evaluation of products

Sample	Texture	Color	Taste	Odor	Overall acceptability
Control	5.8±0.84^a	6.8±1.14^a	6.6±0.84^a	6.6±0.55^a	5.6±1.14^a

Sample	Texture	Color	Taste	Odor	Overall acceptability
Alg 2%	7±1.00^{b}	7.4±1.00^{a}	7.4±0.84^{b}	7.4±0.84^{b}	6.6±0.84^{b}

Different superscript lower-case letters in the same column denote significant differences (p<0.05).

Fresh-cut muskmelon was evaluated in terms of consumer acceptability including odor, color, taste, texture, and overall acceptability. Table 2 shows that all sensory attributes have significant differences (p<0.05) between samples. However, all sensory scores of the alginate coating sample were higher than those of the control sample. Among them, the overall acceptability score obtained was 6.6. This perspective is similar to that of the study by Azarakhsh *et al.* (2014), who also preserved fresh-cut pineapple using alginate coating or Martiñon *et al.* (2014) who preserved fresh-cut cantaloupe using chitosan film. The sample coated with edible film often obtains higher scores. After 9 days of storage, the treated sample still maintains its characteristics such as odor, taste, texture, and color.

Changes in the microbial population of fresh-cut muskmelon in terms of aerobic microbial count, yeast and mold count, *Escherichia coli* and *Salmonella* spp. were carried out at the end of storage. Fresh-cut muskmelon shelf-life was marked by microbial spoilage and juice leakage after 10 days of storage. Table 3 shows that *E. coli* and *Salmonella* spp. were not detected in both samples. The total aerobic microbial count of the treated sample is similar to that of the control sample. On the contrary, the total yeast and mold count of the treated sample is lower than that of the control sample. This shows that alginate coating can prevent the growth of yeast and mold better than aerobic bacteria. Total aerobic plate count in this study was lower than that of fresh-cut carrot ($10^{6.48}$ Cfu/g), tomato ($10^{6.97}$ Cfu/g), etc. (Chung *et al.*, 2011); while total yeast and mold count was also lower than that of ready-to-eat salads ($10^{6.2}$–$10^{7.5}$ Cfu/g) and fresh-cut vegetables ($10^{5.4}$–$10^{7.6}$ Cfu/g) (Jeddi *et al.*, 2014). Essentially, none of the microbial criteria of samples in this study exceeded the limit of 10^8 CFU/g for the total aerobic microbial count and 10^5 CFU/g for the total yeast and mold count as required by the CNERNA-CNRS (1996).

Table 3

Microbiological analysis of products

Sample	Total aerobic plate count (Cfu/g)	*Escherichia coli* (Cfu/g)	*Salmonella* spp. (Cfu/25 g)	Total yeast and mold count (Cfu/g)
Control	6.6×10^5	-	-	2.7×10^3
Alg 2%	6.7×10^5	-	-	9.4×10^2

"-": Not detected

CONCLUSIONS

In general, all alginate concentrations can maintain the quality of fresh-cut muskmelon, their efficiency is better than the control sample. However, among them, the alginate coating concentration of 2% stands out because the decrease in weight loss, sugar content, titrable acidity, and vitamin C content of the product change insignificantly compared to the initial sample. This edible film was recorded without any adverse effect on the sensory acceptability of fresh-cut muskmelon, the overall acceptability score of the product at the alginate coating concentration of 2% (w/v) was also higher than the control sample after 9 days. This confirms that the alginate coating can be applied in post-harvest technology on a large-scale in the future.

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AUTHORS CONTRIBUTIONS

Conceptualization: L.P.T. Quoc; Methodology: L.P.T. Quoc; Data collection: L.P.T. Quoc; Data validation and processing: L.P.T. Quoc; Writing - original draft preparation: L.P.T. Quoc; Writing - review and editing: L.P.T. Quoc.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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