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Effectiveness of Carrageenan Coating to Extend Shelf Life of Watermelon (*Citrullus lanatus*) Fruit during Storage

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Abstract.

Watermelon contains lycopene, a red carotenoid pigment that has strong antioxidant properties. Edible coatings are widely used for extension of shelf life of fruits and vegetables by reduction of moisture loss and gas exchange as well as reduction of the physiological disorders. The main problem of postharvest losses associated with watermelon is rapid loss of firmness, soluble dry matter, and carotenoid. The objective of the present study was to identify the effect of different carrageenan concentrations (0.1%, 0.15%, 0.2%, 0.25%, 0.30%) and storage temperature (5 ^oC, 10 ^oC, 15 ^oC, 20 ^oC) to the weight loss, firmness, total soluble sugar and carotenoid in watermelon (*Citrullus lanatus*) fruits during storage. Moreover, shelf life (0 day, 7 days, 14 days, 21 days and 28 days) of watermelon (*Citrullus lanatus*) fruit in storage also clarified. Results demonstrated that Carrageenan 0.25% and storage temperature 10 ^oC could maintain watermelon (*Citrullus lanatus*) fruit quality for 28 days without any deterioration. This is an opportunity to develop value-added products reducing the postharvest losses, improving nutritional value and generating additional revenue for watermelon growers.

Keywords: *Watermelon, carrageenan, coating, firmness, carotenoid, shelf life, storage*

I. INTRODUCTION

Watermelon is the third most popular fruit vegetable in the world and also the largest among the fruits eaten in hot weather. Flesh color is an important trait of watermelon (Wen'en Zhao et al., 2013). Watermelon (*Citrullus lanatus*) botanically considered as the fruit is belonging to the family Cucurbitaceae (Edwards et al., 2003). It is a large, sprawling annual plant with coarse, hairy pinnately-lobed leaves and yellow flowers. It is grown for its edible fruit, which is a special kind of berry botanically called a pepo. The watermelon fruit has deep green smooth thick exterior rind with grey or light green vertical stripes. There are now eight designated flesh colors in watermelon: white, salmon yellow, orange, crimson red, scarlet red, pale yellow, canary yellow and green (King, S.R. et al., 2009). Inside the fruit is red in colour with small black seeds embedded in the middle third of the flesh. Watermelons range in shape from round to oblong. Rind colours can be light to dark green, with or without stripes. Flesh colours can be dark red, red or yellow. Watermelons can be stored for 14 days at 15°C. Watermelons should not be stored with apples and bananas as the ethylene produced during storage from these fruits hastens softening and development of off flavour to watermelons. Watermelon contains more than 91% water and up to 7% of carbohydrates. It is a rich source of lycopene and citrulline. Watermelon rind contains more amounts of citrulline then flesh. Additionally, watermelon has a number of essential micronutrients and vitamins (Reetu and Maharishi Toma, 2017). Watermelon contains high levels of lycopene that is very effective in protect cells from damage and lower the risk of heart disease. Watermelon extracts help to reduce hypertension and lower blood pressure in obese adults. Watermelon fruit is also a good source of potassium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. Thus, it prevents against stroke and coronary heart diseases.

Watermelons generally are not refrigerated when shipped domestically. However, refrigerated storage and transit may be used to extend the shelf life during export shipment. The recommended range is 10 to 15ºC. At lower temperatures, fruit are susceptible to chilling injury and decay and loss of color. At higher temperatures, fruit are subject to decay and sugar loss (Chisholm and Picha, 1986). Prestorage conditioning at 26ºC for 4 days reduces development of chilling injury and increases the percentage of marketable fruit following storage (Picha, 1986). Handling and processing of watermelon fruits is very teddies work due to the big size of fruits, which need accurate information about the physical and mechanical properties.

There was only one research mentioned to watermelon (*Citrullus lanatus*) preservation using edible coating. A study evaluated the effectiveness of an improved multilayered antimicrobial alginate-based edible coating in increasing the shelf life of fresh-cut watermelon without affecting its quality attributes (R.E.Sipahi et al., 2013). The practice of coating watermelon (*Citrullus lanatus*) resistant to soilborne pathogens may be considered an imperative to present-day commercial watermelon cultivation, especially in areas of intensive production. The objective of the present study was to identify the effect of different Carrageenan concentrations (0.1%, 0.15%, 0.20%, 0.25%, 0.30%) and storage temperature (5 ^oC, 10 ^oC, 15 ^oC, 20 ^oC) to the weight loss, firmness, total soluble sugar and carotenoid in watermelon (*Citrullus lanatus*) fruits during preservation. Moreover, shelf life (0 day, 7 days, 14 days, 21 days and 28 days) of watermelon (*Citrullus lanatus*) fruit in storage also clarified.

II. MATERIALS AND METHOD

2.1 Materials

We collected watermelon (*Citrullus lanatus*) fruits in Hau Giang province, Vietnam. They were cultivated following VietGAP to ensure food safety. After harvesting, collected nuts were stored at a temperature of 20˚C and they were conveyed to laboratory within 8 hours for experiments. These fruits were tumbled thoroughly under turbulent moving to remove dirt, dust and adhered unwanted material. Beside watermelon we also used other materials during the research such as Carrageenan, ethyl alcohol, propylene glycol. Lab utensils and equipments included digital weight balance, penetrometer, refractometer, biuret, and refrigerator.

Figure 1. Watermelon (*Citrullus lanatus*) fruit

2.2 Methods

2.2.1 Preparation of edible coatings

Carrageenan (0.1%, 0.15%, 0.2 %, 0.25%, 0.30%) was prepared by dissolving 0.2g, 0.3g, 0.4 g, 0.5 g, 0.6g of carrageenan powder in 200 ml of water ethyl alcohol mixture (3:1) at 80 ^oC and stirred for 10 min using magnetic stirrer. Ethyl alcohol was added in order to reduce drying time and obtain a transparent and shiny coating. 2% volume of propylene glycol was also added in the formulation as plasticizer. Watermelon (*Citrullus lanatus*) fruits were dipped in the film forming dispersions for 1min. After that, they were hung up and dried at room temperature with natural convection for 2– 3 h and then stored in refrigerator for further experiments.

2.2.2 Fruit quality assessments

The physical and chemical compositions including weight loss (%), firmness (N), total soluble solid (^{o}Brix), and carotenoid (mg/ml) in fresh and coated watermelon (*Citrullus lanatus*) were analyzed.

Weight loss (%): To evaluate weight loss, separate samples in 3 replicates of each treatment were used. The same samples were evaluated for weight loss each time at weekly intervals until the end of experiment. Weight loss was determined by the following formula: Weight loss (%) = [(A−B)/A] x 100 where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after storage intervals (A.O.A.C., 1994).

Firmness (N): Firmness was measured as the maximum penetration force (N) reached during tissue breakage, and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm. Watermelon (*Citrullus lanatus*) was cut into halves and each half was measured in the central zone.

Total soluble solids (^{o}Brix): Individual watermelon (*Citrullus lanatus*) fruit from each of the treatment was grinded in an electric juice extractor for freshly prepared juice. Soluble solids content was measured using T/C hand refractometer in ^{o}Brix.

Carotenoid (mg/ml): Carotenoid content was measured by near infrared spectroscopy (Elena Tamburini et al., 2017)

2.2.3 Effect of different Carrageenan concentrations to weight loss, firmness, total soluble solid, carotenoid of watermelon (Citrullus lanatus) fruit

Effect of different carrageenan concentrations (0.1%, 0.15%, 0.20%, 0.25%, 0.30%) to weight loss (%), firmness (N), total soluble solid (^{o}Brix), carotenoid (mg/ml) was assessed. All samples were preserved in 10^{o}C for 7 days.

2.2.4 Effect of storage temperature to shelf life of watermelon (Citrullus lanatus) fruit

After finding the appropriate Carrageenan coating concentration (%), shelf life of watermelon (*Citrullus lanatus*) fruit was also evaluated by the effect of different storage temperature. Watermelon (*Citrullus lanatus*) fruits which were set in trays in were divided into four groups (5 ^{o}C, 10 ^{o}C, 15 ^{o}C and 20 ^{o}C). Weight loss, firmness, total soluble solid, carotenoid values were assessed during preservation (7 days) to demonstrate the appropriate storage temperature.

2.2.5 Shelf-life of watermelon (Citrullus lanatus) fruit during preservation

After finding the appropriate carrageenan concentration, storage temperature; shelf life of watermelon (*Citrullus lanatus*) fruit during preservation was also evaluated by sampling at different intervals (0, 7, 14, 21, 28 days). Weight loss, firmness, total soluble solid, carotenoid values were assessed.

2.3 Statistical analysis

The Methods were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT). Statistical analysis was performed by the Statgraphics Centurion XVII.

III. RESULTS & DISCUSSION

3.1 Physical and chemical characteristics in fresh watermelon (*Citrullus lanatus*) fruit

The physical and chemical compositions in fresh watermelon (*Citrullus lanatus*) fruit were analyzed. Resuts were mentioned in table 1.

3.2 Effect of different Carrageenan concentrations to weight loss, firmness, total soluble solid, carotenoid of watermelon (*Citrullus lanatus*) fruit

Effect of different Carrageenan concentrations (0.1%, 0.15%, 0.20%, 0.25%, 0.30%) to weight loss (%), firmness (N), total soluble solid (^{o}Brix), carotenoid (mg/ml) was assessed. All samples were preserved in 10^{o}C for 7 days. Results were depicted in table 2. As clearly shown in table 2, all edible coatings significantly ($P< 0.05$) retard the changes in watermelon (*Citrullus lanatus*) weight loss, firmness, total soluble solid and carotenoid as compared to control samples. 0.25% Carrageenan coating was appropriated for further experiments.

Table 1. The chemical compositions in fresh watermelon (*Citrullus lanatus*) fruit

Parameter	Firmness (N)	Total soluble solid (°Brix)	Carotenoid (mg/g)
Value	1978.44±11.3	14.15±0.02	23.41±0.01

Table 2. Effect of different Carrageenan concentrations to weight loss (%), firmness (N), total soluble solid (°Brix), carotenoid (mg/g) of watermelon (*Citrullus lanatus*) fruit during preservation (10°C after 7 days)

Carrageenan **concentration (%)**	**Weight loss (%)**	**Firmness (N)**	**Total soluble solid (°Brix)**	**Carotenoid (mg/g)**
Control	5.27±0.01[a]	1802.19±11.1[c]	12.04±0.03[c]	20.02±0.00[c]
0.1	4.12±0.03[ab]	1841.39±10.3[bc]	12.74±0.02[bc]	20.41±0.01[bc]
0.15	3.94±0.01[b]	1883.28±10.2[b]	12.87±0.02[b]	20.83±0.00[b]
0.20	3.40±0.00[bc]	1904.08±11.1[ab]	13.03±0.00[ab]	21.01±0.02[ab]
0.25	**2.23±0.02[c]**	**1960.11±10.2[a]**	**13.40±0.01[a]**	**21.21±0.01[a]**
0.30	2.17±0.01[c]	1965.02±11.3[a]	13.42±0.02[a]	21.25±0.01[a]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 3. Effect of storage temperature to weight loss (%), firmness (N), total soluble solid (°Brix), carotenoid (mg/ml) of watermelon (*Citrullus lanatus*) fruit

Storage temperature (°C)	Weight loss (%)	Firmness (N)	Total soluble solid (°Brix)	Carotenoid (mg/ml)
5 °C	2.20±0.02[b]	1963.48±10.0[a]	13.42±0.01[a]	21.23±0.02[a]
10 °C	**2.23±0.02[b]**	**1960.11±10.2[a]**	**13.40±0.01[a]**	**21.21±0.01[a]**
15 °C	2.49±0.02[ab]	1824.90±10.4[ab]	12.98±0.00[ab]	19.93±0.01[ab]
20 °C	3.59±0.01[a]	1737.75±10.1[b]	12.37±0.03[b]	18.34±0.02[b]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 4. Shelf life of watermelon (*Citrullus lanatus*) fruit during preservation

Preservation time (days)	Weight loss (%)	Firmness (N)	Total soluble solid (°Brix)	Carotenoid (mg/g)
0	0[d]	1960.11±10.2[a]	13.40±0.01[a]	21.21±0.01[a]
7	1.03±0.00[c]	1949.49±10.4[ab]	13.35±0.01[ab]	21.19±0.02[ab]
14	2.34±0.02[b]	1942.84±10.1[b]	13.04±0.02[b]	21.08±0.01[b]
21	3.11±0.03[ab]	1939.12±10.1[bc]	12.92±0.01[bc]	21.03±0.00[bc]
28	4.28±0.01[a]	1932.48±10.4[c]	12.76±0.00[c]	21.00±0.01[c]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

A study evaluated the effectiveness of an improved multilayered antimicrobial alginate-based edible coating in increasing the shelf life of fresh-cut watermelon without affecting its quality attributes. A set of solutions containing sodium alginate (0.5, 1, 2 g/100 g), beta-cyclodextrin and microencapsulated *trans*-cinnamaldehyde (natural antimicrobial agent), pectin, and calcium lactate were used as coating systems and made into a coating using the layer-by-layer (LbL) technique. The samples were coated using the layer-by-layer dipping technique and stored at 4 °C for 15 days. A consumer acceptance test showed high acceptance ($P < 0.05$) of the coated samples except for the 2 g/100 g alginate coating. Texture (firmness) was particularly enhanced ($P < 0.05$) by application of the coating. Both the 1 and 2 g/100 g alginate coatings extended the shelf life of fresh-cut watermelon from 7 (control) to 12–15 days. The application of the multilayered edible coating with 1 g/100 g alginate will maintain the quality and sensory acceptance of fresh-cut watermelon while extending its shelf life (R.E.Sipahi et al., 2013).

3.3 Effect of storage temperature to weight loss, firmness, total soluble solid, carotenoid of watermelon (*Citrullus lanatus*) fruit

After finding the appropriate Carrageenan coating concentration (%), shelf life of watermelon (*Citrullus lanatus*) fruit was also evaluated by the effect of different storage temperature. Results were elaborated in table 3. Storage temperature for watermelon (*Citrullus lanatus*) should be 10 °C which was appropriated for further experiments.

Watermelons stored at 21°C had increased pH, chroma, and carotenoid content compared to fresh fruit. Compared to fresh fruit, watermelons stored at 21°C gained 11−40% in lycopene and 50−139% in β-carotene, whereas fruit held at 13 °C changed little in carotenoid content. These results indicate that carotenoid biosynthesis in watermelons can be affected by temperature and storage (Penelope Perkins-Veazie, and Julie K. Collins, 2006). Melon fruits coated and stored at 2°C perform better than fruits stored at 9°C and shelf-life room, while fruits held at 9°C did better than those stored at shelf-life room (Nasiru Alhassan, Adams Abdul-Rahaman, 2014).

3.4 Shelf-life of watermelon (*Citrullus lanatus*) fruit during preservation

After finding the appropriate 0.25% Carrageenan concentration, storage temperature at 10°C; shelf life of watermelon (*Citrullus lanatus*) fruit during preservation also evaluated by sampling in different intervals (0, 7, 14, 21, 28 days). Results were also mentioned in table 4. Quality of watermelon (*Citrullus lanatus*) fruits which were coated by 0.25% Carrageenan and stored at 10 °C was maintained for 28 days without any deterioration.

A study evaluated the effectiveness of packaging using a microencapsulated β-cyclodextrin and *trans*-cinnamaldehyde complex incorporated into a base chitosan matrix on the shelf life of fresh-cut melon that were coated with a multilayered coating system using a polypropylene tray. The multilayered antimicrobial coating improved the shelf life of fresh-cut melon (up to 15 days), compared with the controls (7 days). Coated samples were firmer, maintained colour and total carotenoids content and showed less weight loss than the controls ($P < 0.05$). Among the packaging treatments, the Ziploc® lid was the most effective in maintaining shelf life (Samira Pereira Moreira et al., 2014). The use of chitosan alone and together with montmorillonite and Clove essential oil were effective in maintaining the sensory and microbiological characteristics for a longer time of melon (Raquel Costa Chevalier et al., 2016).

IV. Conclusion

The right edible coating formulation could reduce water loss and gas exchange rates as well as represent an excellent way of incorporating additives to control reactions that are detrimental to produce quality during storage and transport. Edible coatings are thin films that can be used as a new trend in post-harvest by reducing moisture and solute migration, gas exchange, respiration, and oxidative reaction rates, as well as by reducing physiological disorders. Edible coatings applied on many products to provide a barrier against external elements and therefore increase shelf life. This research has successfully found out the appropriate conditions for maintaining watermelon (*Citrullus lanatus*) fruit quality such as Carrageenan coating concentration, storage temperature as well as extending product shelf life. The increase in shelf life of watermelon fruit would, therefore, be an advantage to the growers.

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