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Effect of glucomannan and potassium sorbate on quality and shelf life of fresh-cut cantaloupe

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ABSTRACT

The objective of this research was to study the effects of glucomannan, and potassium sorbate on the quality and shelf-life of fresh-cut cantaloupes, which were stored at 6±2°C for 9 days. The concentrations of glucomannan studied were 0.05, 0.10, 0.15 and 0.20% (w/v). Results indicated that the coating solution containing 0.5% (w/v) of calcium chloride and 0.05% (w/v) glucomannan could help maintain weight loss, hardness and firmness, of the samples. However, the increase of glucomannan concentration to 0.10, 0.15, and 0.20% (w/v) showed adverse effects to most quality aspects of the fresh-cut samples. The microbial load of the coated cantaloupe at all concentrations of glucomannan was still high and could extend the shelf life of the samples to 1 day or less. Subsequently, the optimal concentration of potassium sorbate was investigated at 0.05, 0.10, and 0.15% (w/v). Results indicated that the coating solution containing 0.5% (w/v) of calcium chloride and 0.05% (w/v) glucomannan could inhibit the microbial growth, especially bacteria at all concentrations of potassium sorbate studied. Additionally, the coating mixture with potassium sorbate at 0.15% (w/v) could preserve the fresh-cut cantaloupes for a maximum of 5 days with safer microbial loads for commercial use.

Keywords: fresh-cut cantaloupe; glucomannan; potassium sorbate

1. INTRODUCTION

Cantaloupe (*Cucumis melo* L., var. *cantaloupensis*) is a popular fruit, mainly, for its sweet taste, pleasant aroma, high dietary fiber, abundant nutrients, and bioactive components, including vitamins A and C, folic acid and beta-carotene (Beaulieu and Lea, 2007). This fruit has been sold both as a whole fruit and ready-to-eat fresh-cuts. Fresh-cut fruit requires minimal processing methods such as washing, peeling, cutting, deseeding, slicing, and dipping depending on the fruit type (Yousuf et al., 2018). Minimal processing has the advantages of health benefit, convenience, and retaining of flavour and nutrients. However, fresh-cut indicates shorter shelf life, because cutting or slicing process could destroy tissue and causes weight loss, moisture transfer, and surface browning (Saltveit, 1997). The change metabolic activities of fresh-cut fruit causes texture breakdown, increased ripening and respiration rate (Raybaudi-Massilia et al., 2008). Additionally, microbial contamination causes the rapid deterioration of cut fruits, leading to shorter shelf-lives

Coating is generally done to improve the food appearance and helps maintain the quality and extend the shelf life of fresh-cut fruits (Mantilla et al., 2013). Coating should be safe, natural, and free of concerns, and must not affect the sensory characteristics of fruit (Singh et al., 2018). Coating can be used for the control of moisture transfer, gas exchange, and oxidation processes (Rojas-Graü et al., 2009). The edible coating used for materials can be grouped by related functions such as anti-browning agent, antimicrobial agent, improved firmness and as colorants (Singh et al., 2018). Edible coatings are used in a wide range of fresh and fresh-cut products and may also serve as food additive carriers. Raybaudi-Massilia et al. (2008) used alginate-based coating to increase firmness of fresh-cut melon (*var. inodorus*) and Zambrano-Zaragoza et al. (2017) reported the use of xanthan gum coating to maintain juice leakage of fresh-cut melon (*var. cantaloupe*).

Glucomannan, a polysaccharide derived from konjac tubers (*Amorphophallus konjac*), is composed of 1,4 linked β-mannose and β-glucose at the ratio of 1.6:1 with some acetyl groups (Lin and Huang, 2003). Glucomannan has been used as a gelling agent, glazing agent, and stabilizer in many food products. Supapvanich et al. (2012) reported that glucomannan coating could reduce weight loss and enhance inhibition of browning in fresh-cut rose apple. Sopondilok et al. (2010) reported that glucomannan could be used for delaying the softening and ripening of papaya cultivar. In addition, calcium chloride ($CaCl_2$) has been used as firming agent for improving the texture of fresh-cut fruits. The use of 1% $CaCl_2$ with polysaccharide-based coating could maintain the firmness of apple pieces (Rojas-Graü et al., 2008). Antibacterial food additives including potassium sorbate is widely used in many food products to extend the shelf life. Baldwin et al. (1996) reported that addition of 0.1% potassium sorbate at low pH could inhibit the microbial growth of fresh-cut apples.

However, there were no report on the use of glucomannan for preserving quality of fresh-cut cantaloupe in the literature. Therefore, this research aimed to study the use of glucomannan with $CaCl_2$ and potassium sorbate to extend the shelf life of fresh-cut cantaloupe. The effects of coating on color, appearance, weight loss, total soluble solids, pH, acid content, and textural and microbial properties of fresh-cut cantaloupes were investigated.

2. MATERIALS AND METHODS

2.1 Materials

Cantaloupe (*Cucumis melo* L var. *cantaloupensis*) were purchased from local market in Bangkok province, Thailand and kept for one day at 25°C before the fresh-cut processing. Glucomannan from Konjac, calcium chloride and potassium sorbate were purchased from Chemipan Co., Ltd. (Thailand).

2.2 Preparation of edible coating

Fresh cantaloupe at selected maturity indicated by its skin color (light green), weight (1.0 to 1.2 kg.) and hardness (1.50 to 2.00 kg) was used for the experiments. Before coating, whole cantaloupe were immersed in 0.01% (v/v) sodium hypochlorite solution for 5 min, washed with tap water for 1 min, peeled manually, and cut into 8 portions longitudinal first and into pieces with thickness around 2.5 cm. The solution for the coating was prepared from 0.5% (w/v) calcium chloride with glucomannan at four different concentrations, 0.05, 0.10, 0.15 and 0.20% (w/v). Cantaloupe pieces were soaked in each coating solution for 3 min. After soaking, the excess water on samples surface was air-dried for 5 min at room temperature (27-33°C) before packing in a plastic tray (200×145×45 mm^3), covered with a polypropylene film (0.02 mm), and stored at 6±2°C for 9 days. The quality parameters for the fresh-cut cantaloupe such as color, weight loss, total soluble solids, pH and titratable acid content, texture/ hardness, and microbiological evaluation were determined at Day 0, 1, 3, 6, and 9. The optimal concentration of glucomannan at 0.05% (w/v) was selected for further study to investigate the effect of potassium sorbate at 0.05, 0.10, and 0.15% (w/v) for antimicrobial effect on fresh-cut cantaloupe.

2.3 Properties of fresh-cut cantaloupe

2.3.1 Color and appearance

The color of fresh-cut cantaloupe was measured using a Munsell book of color (2.5R, pale yellow color) to 10RP (yellow-orange color) and results were reported as hue, value and chroma.

2.3.2 Weight loss

Weight loss of fresh-cut cantaloupe was measured using a digital balance (AND GR-200, Japan). The weight loss was calculated with following Equation:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100 \qquad (1)$$

2.3.3. Total soluble solids, pH and titratable acid content

The cantaloupe pieces from each treatment were crushed using an extractor (Kenwood, UK), and the total soluble solids in the juice were measured with a hand refractometer (Vigor V2459, Germany). The results were reported as °Brix and the measurement was performed in triplicate. pH of cantaloupe was measured at 25°C with a hand-held pH meter (OAKTON pHTestr10, USA). The titratable acid content was determined by titrating the cantaloupe juice against a 0.1 M NaOH solution using phenolphthalein as an indicator (The Association of Official Analytical Chemists, 2000). The acid content was calculated according to following Equation:

$$\text{Acid content (\%)} = \frac{\text{N base} \times \text{mL base} \times \text{meq.wt of citric acid}}{\text{Volume of cantaloupe juice (mL)}} \times 100 \qquad (2)$$

where N base is normality of sodium hydroxide of solution, mL base is volume of sodium hydroxide solution, and meq.wt of citric acid (anhydrous form) is 0.06404.

2.3.4. Texture analysis

The hardness and firmness of fresh-cut cantaloupe were measured using a TA.XT Plus Texture Analyzer (Stable Micro Systems, USA) with a 2-mm diameter stainless steel needle probe (P/2N). The hardness is the measurement of the maximum force required to penetrate the fruit to a specified depth, while the firmness is an indicator for level of fruit maturity, which is measured as the area under the force and time curve. The measurement conditions were pre-test speed of 1.5 mm/s, test speed of 1.5 mm/s, post-test speed of 10 mm/s, penetrating distance of 4 mm into the cantaloupe and trigger force of 25 g. (Benitez et al., 2013). Ten measurements were carried out for each treatment.

2.3.5. Microbial evaluation

Total plate counts, and yeast and mold counts were determined by using 25 g cantaloupe pieces from each treatment, transferring them into sterile plastic bags mixed with 225 mL of maximum recovery diluent (MRD) (Difco, USA), and homogenizing for 1 min. Serial dilutions were made using MRD, followed by pour-plate technique in triplicate on plate count agar (PCA) (HiMedia Nashik, India) and incubated at 37°C for 2 days to count for total bacteria. Dichloran rose bengal chloramphenicol agar (DRBC) (Difco, USA) was used for 5 days incubation at 25°C to count for yeast and mold. The microbial colonies were reported as CFU/g of sample.

2.4. Statistical analysis

The data were analyzed by analysis of variance (The Association of Official Analytical Chemists) using SPSS Ver 19. Statistical differences were obtained using the Duncan's multiple range test (p<0.05).

3. RESULTS AND DISCUSSION

3.1 Color and appearance

Color and appearance are the major factors for consumer perception. Uncoated (control) and coated cantaloupe cut fruits exhibited hue number of 7.5 YR as shown in Figure 1. Value/chroma of the control changed from 8/4 (pink) to 8/6 (reddish yellow) during the storage, while the samples coated with glucomannan at all concentrations changed to 7/6 and 7/8 (dark reddish yellow) indicating good color from Day 1 through the storage. The differences in the fruit color might be due to the different respiration rates and metabolism caused by the coating. However, the coating with 0.15 and 0.20% glucomannan showed a thick gel cover on the fruit surface, which could present an unacceptable appearance to the consumers.

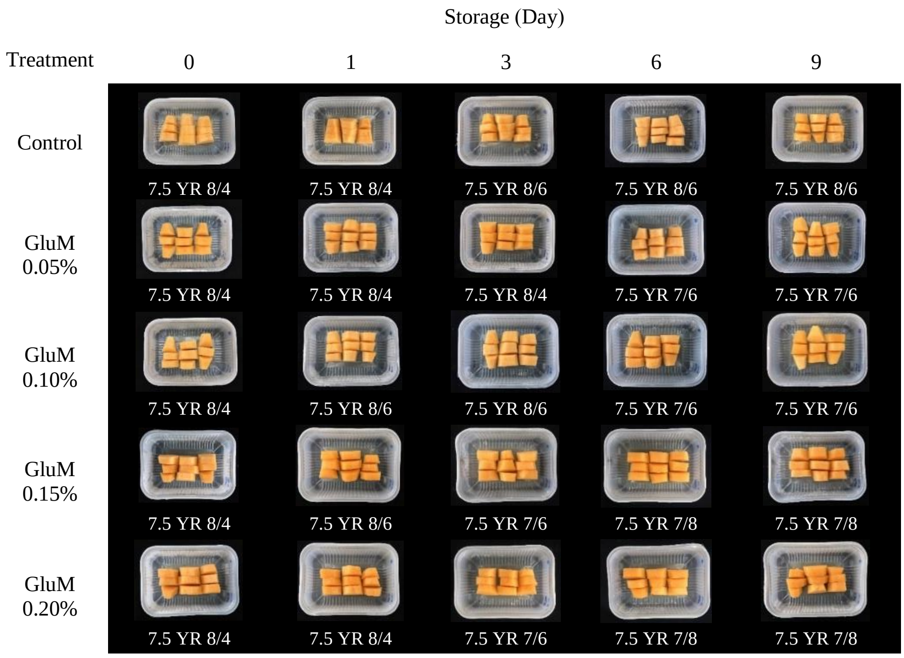

Figure 1 Effect of glucomannan (GluM) treatment at different concentrations on color and appearance of fresh-cut cantaloupes during the storage at 6±2°C for 9 days

3.2 Weight loss

Weight loss is apparently one of the quality indices in the shelf life determination of cut fruits. The weight losses for 9 days during the storage at 6±2°C (Figure 2A) show that the moisture loss for uncoated samples was significantly (p<0.05) higher than for coated samples during the storage. The cantaloupe coated with 0.5% $CaCl_2$ and 0.05% glucomannan indicated the lowest weight loss at 0.98-1.99% during the storage. Moisture evaporation through the fruit surface is a normal metabolic process. In addition, fruit lost cuticle and outer tissues during the cutting process, which resulted in shriveling and deterioration of the fruit and enhanced the moisture loss (Khaliq et al., 2015; Ngamchuachit, 2017). Similar result was reported by Hongkulsup et al. (2007) who noted that glucomannan coating could retard weight loss of intact rose apple fruit during the storage. However, the increase of glucomannan concentration from 0.05% to 0.20% tended to increase the weight loss of the fresh-cut cantaloupe. This might be because of the gelation of the glucomannan, resulting in a thick gel layer over the fruit surface. The gel might crack due to shriveling and lose the moisture via vapor evaporation from the fruit samples.

3.3 Total soluble solids, pH and titratable acid content

Total soluble solids (TSS), one of the fruit maturity indices, slightly increased for both uncoated and coated cantaloupes along the storage times, as shown in Figure 2B. The glucomannan at 0.15 and 0.20% concentrations did not affect the change of TSS compared to the control (12.23-12.47°Brix), while glucomannan at 0.05 and 0.10% significantly increased the TSS during the storage (12.03-12.30°Brix). Similar result was reported by Sangsuwan et al. (2008) that the TSS of the fresh-cut cantaloupe increases during storage along with the moisture loss. The increase in TSS might have resulted from the breakdown of carbohydrates into simple sugar and glucose (Kittur et al., 2001).

The pH of all cantaloupe samples decreased during the storage (Figure 2C). The pH of the control changed from 6.70 at Day 1 to 6.50 at Day 9, while the samples coated with 0.05, 0.10, 0.15 and 0.20% indicated the pH changes from 6.73 to 6.27, 6.57 to 6.33, 6.60 to 6.50, and 6.70 to 6.37, respectively. The titratable acid content corresponded to the pH change that increased over time (Figure 2D). Changes in pH and titratable acid content of fresh-cut cantaloupes could be due to microbial growth (Koh et al., 2017). Higher acidity is preferred during storage because they correlated with lower pH values, thereby preventing the early growth of microorganisms in fresh-cut fruits, which is crucial for the quality control and shelf life extension of the products (Mantilla et al., 2013).

3.4 Texture analysis

The coating with 0.05% (w/v) glucomannan could maintain the hardness and firmness of the fresh-cut cantaloupe better than the control, as shown in Figure 3A and 3B. Fruit texture such as hardness and firmness are important quality concerns related to sensory perception of the consumers. The firmness of fresh-cut fruit is caused by the deterioration of the cell wall structure and the turgor pressure inside the cell membrane (Shackel et al., 1991). The control, the sample without coating, exhibited high relative hardness and firmness at day 3 to day 9. Glucomannan is a thickener and a gelling agent, so it helped in preventing dehydration and maintaining the firmness (Thomas, 1997). The coating with glucomannan at 0.10, 0.15, and 0.20% (w/v) also helped maintain the texture of the coated fruits compared to the control until day 3, but not after that. Firmness of the samples corresponded with their hardness. Softening observed in fresh-cut fruits may be due to the pectic acid undergoing acid hydrolysis (Ponting et al., 1971). The increase of glucomannan concentration from 0.05% to 0.20% tended to decrease the hardness and firmness of the fresh-cut cantaloupes because a crack in the coated gel of higher glucomannan concentration was observed, which might lead to the moisture loss from the fruit samples and become softer.

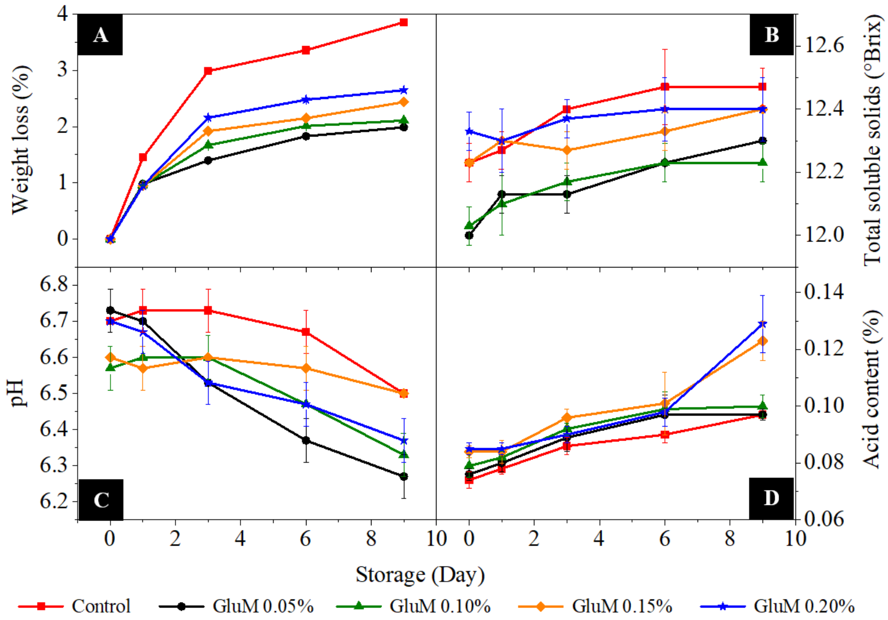

Figure 2 Effect of concentration of glucomannan (GluM) on weight loss (A), total soluble solids (B), pH (C), and acid content (D) of fresh-cut cantaloupes during the storage at 6±2°C for 9 days

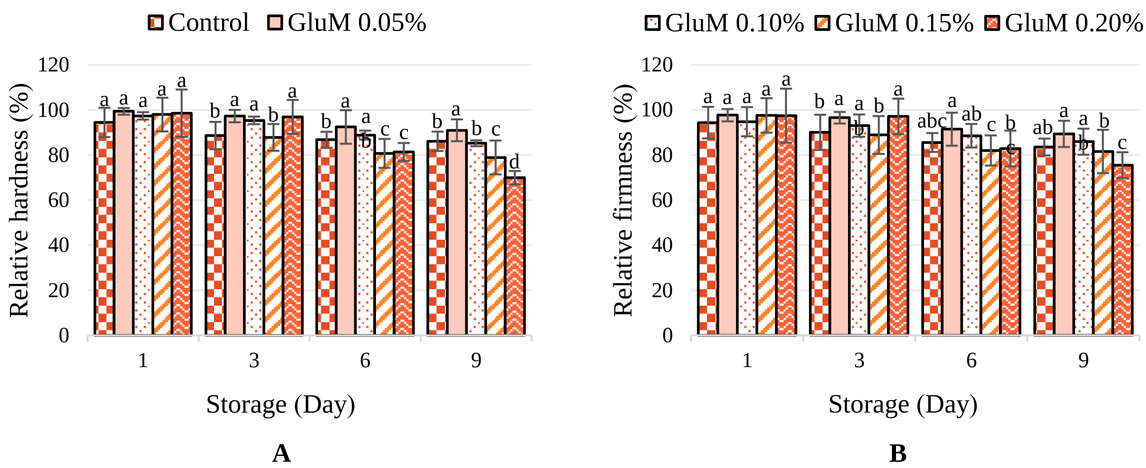

Figure 3 Effect of glucomannan concentrations and 0.5% $CaCl_2$ on relative hardness (A) and firmness (B) of fresh-cut cantaloupes during the storage at 6±2°C for 9 days

Note: Different superscript letters for different coating solution on the same day indicate significant difference (p<0.05)

3.5 Microbiological evaluation

The microbiological load in food products can also be one of the quality indices exhibiting safety and is related to the quality and shelf life of the food. The coating of fresh-cut cantaloupes in 0.05% glucomannan with 0.5% $CaCl_2$ could improve the fruits in terms of texture and other properties to 9 days, compared to less than 3 days for control. However, considering for the microbial load, the shelf life of control and the coated samples were only less than 1 day and 1 day, respectively.

However, the use of antibacterial potassium sorbate significantly reduced the microbial loads in cut-fruits, as shown in Table 1. The microbial load of uncoated cantaloupe was significantly (p<0.05) higher than cantaloupe coated with 0.05% glucomannan, 0.5% $CaCl_2$ and added with 0.05, 0.10, and 0.15% potassium sorbate during the storage. Similar results were reported by Kowalczyk et al. (2017) for using potassium sorbate with carboxymethylcellulose-base in delaying the fungal growth rates of pear fruit. On Day 9 of the storage, total plate count was 1.79×10^6 CFU/g which exceeded the standard recommended levels set by the Department of Medical Sciences (2017), namely total plate count, yeast and mold counts have to be less than 1×10^6, 1×10^3, and 5×10^2 CFU/g, respectively. Coating with 0.05 and 0.10% of potassium sorbate indicated the microbial loads above the standard recommendations for yeast and mold counts at 8.67×10^2 and 5.97×10^2 CFU/g, respectively on Day 6 of the storage. It meant that the use of potassium sorbate could extend the shelf life of the fresh-cut cantaloupes from 1 day to 5 days.

Table 1 Effect of potassium sorbate (KS) at different concentrations on microbial load of fresh-cut cantaloupe during the storage

Treatment	Total plate count (CFU/g)					Yeast Mold count (CFU/g)				
	Day 0	**Day 1**	**Day 3**	**Day 6**	**Day 9**	**Day 0**	**Day 1**	**Day 3**	**Day 6**	**Day 9**
Control	$2.30\times10_a$	$1.57\times10^2{}_a$	$1.35\times10^3{}_a$	$1.67\times10^4{}_a$	$1.79\times10^6{}_a$	$8.00\times10_a$	$2.50\times10^2{}_a$	$1.47\times10^3{}_a$	$1.07\times10^4{}_a$	$1.15\times10^5{}_a$
KS 0.05%	$1.00\times10_a$	$2.70\times10_b$	$2.13\times10^2{}_b$	$5.73\times10^3{}_b$	$1.17\times10^4{}_b$	$1.30\times10_b$	$3.30\times10_b$	$1.23\times10^2{}_b$	$8.67\times10^2{}_b$	$2.12\times10^3{}_b$
KS 0.10%	$0.70\times10_a$	$1.00\times10_b$	$1.70\times10^2{}_b$	$3.13\times10^3{}_c$	$7.67\times10^3{}_b$	$0.30\times10_b$	$2.30\times10_b$	$9.00\times10_b$	$5.97\times10^2{}_{bc}$	$1.95\times10^3{}_b$
KS 0.15%	$0.30\times10_a$	$0.70\times10_b$	$1.03\times10^2{}_b$	$1.53\times10^3{}_c$	$7.34\times10^3{}_b$	$0.00\times10_b$	$2.00\times10_b$	$6.67\times10_b$	$3.83\times10^2{}_c$	$1.76\times10^3{}_b$

Note: Different subscript letters in the same column indicate significant difference (p<0.05)

4. CONCLUSION

The coating of fresh-cut cantaloupe with 0.5% of calcium chloride and glucomannan at 0.05, 0.10, 0.15 and 0.20% (w/v) could help in maintaining the desirable color and appearance better than the uncoated fruits. However, the 0.05% glucomannan seemed to be the optimal concentration to maintain the weight loss, and preserve hardness and firmness compared to the control during storage. However, the solution mix did not improve the antibacterial capacity of the coating. The use of the potassium sorbate at 0.05-0.15% (w/v) concentrations could help improve the antibacterial capacity of the dip solutions for fresh-cut fruit and extend their shelf lives to around 5 days compared to a very short shelf life of less than 1 day for the control.

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