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Evaluation of Plasticizer Addition in Composite Edible Coating on Quality of Fresh-Cut Mangoes during Storage

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Evaluation of Plasticizer Addition in Composite Edible Coating on Quality of Fresh-Cut Mangoes during Storage

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Abstract. A composite edible coating made from carrageenan - beeswax with two plasticizers was used to cover fresh-cut mangoes. The purpose of this research was to develop edible film with plasticizer treatment and investigate the effect of an edible coating on quality changes in fresh-cut mangoes during refrigerated storage. The film-forming solution was poured onto an acrylic plate 20x20 cm^2 and dried at 50 °C for 24 hours in a cabinet dryer. Coated and uncoated mangoes were placed into styrofoam then over-wrapped with cling wrap and stored at 6°C for 6 days. Edible films containing two plasticizers had a higher thickness, water vapor transmission rate (WVTR), and solubility than the single plasticizer film. It was found that edible coatings could preserve a fresh-cut mango quality by reducing weight loss, delaying an increase in total soluble solids, maintaining pH, total acidity and growth of microorganisms. It also indicated no difference in sensory perception between the coated and the uncoated fresh-cut mangoes.

1. Introduction

Mango (*Mangifera indica* L.) is a seasonal and climacteric fruit, which is cultivated most land in Indonesia [1]. Fresh-cut ready to eat fruits have become important, for expanding food industry. Increase in consumer demand for food available in fresh and convenient condition is an opportunity to fresh-cut server mango [2]. Consumer acceptance and important consideration in marketing is determined by internal and external fruit quality, on the basis of freshness and appearance of fruit at the time of purchase [3]. One of the minimal processing of fresh fruit is mechanical operations, such as peeling, slicing, or cutting. However, minimal processing operation can affect the integrity of fruits, giving a negative effect on product quality such as texture weight loss, breakdown, leakage of nutrients, browning, off-flavor development and possibility increase in the presence of microorganisms on fruit surface which may endanger the safety of fresh-cut fruits [4]. Therefore, alternative methods were needed to maintain the quality attributes of fresh-cut mango during handling, distribution and retail sale [3].

Thin layer of edible materials is having in edible film and coating. It is applied to the surface of food products, friendly with an environment that offers substantial advantages for shelf-life enhancement of many food products [5]. Edible coating affects oxygen partial pressure and metabolism of fresh food, help to retain volatile components, control moisture migration between a food product and an environment protecting it from deterioration and improving textural quality, and decrease the risk of pathogen growth [6]. Edible films are an answer to consumer demand for more natural products and the lower contamination of the environment because they are formed of fully biodegradable and biocompatible polymer derived from natural sources including protein, polysaccharides, and lipids. This research becomes importantly in scientific and industrial field interest worldwide [7]. Hence, natural coating materials which can preserve fresh fruits and retain their quality are highly desired.

Generally, the coating made of hydrophilic substances, such as polysaccharides including carrageenan, have a good mechanical property and a good barrier against gas transfer [8]. Carrageenan is a complex mixture of several polysaccharides and is derived from red seaweed [9] that has a high potential as a film-forming. However, hydrocolloid films are characterized by their poor water vapor permeabilities. Hydrophobic properties of lipid, such as carnauba wax and beeswax, can overcome this weakness by exploiting their great water barrier properties [10].

The other substance like plasticizer is added to improve the mechanical properties of coatings. Major plasticizers have been used polyols such as glycerol, polyethylene glycol, and sorbitol, besides, disaccharides such as sucrose and monosaccharides (e.g., fructose, glucose and mannose) [11]. Type and amount of plasticizers affect properties of the coating [12]. Hence, their polymer types and optimum concentration of plasticizers should be determined for the success of its use in a variety of condition.

Strong interactions can occur between plasticizers (plasticizer-plasticizers interactions) when some plasticizers are used in the film matrix; which can improve certain functional properties of the film [**13**]. The starch-based edible film shown better results when film made from a combination of glycerol-sorbitol 1: 1 as a plasticizer than using glycerol or sorbitol separately [14].

A number of studies were interesting and very promising was reported, which showed minimally processed fruits and vegetables and efficient improvement of quality and safety of fresh fruit and vegetables [5]. Some studies reported that applying a chitosan coating on sliced mangoes effectively prolong the quality attributes and extends their shelf life during storage at 6 °C for 7 days [6; 15]. A polysaccharides coating did not consistently improve the quality of cut mango slices, and the addition of calcium ascorbate with citric acid and N-acetyl-L-cysteine could maintain cut mango slices attractiveness in storage by keeping light color [16]. The coating of papaya using carrageenan with the addition of glycerol as the plasticizer and showed that carrageenan of 0.78% (w/v) and glycerol of 0.85% (w/v) were able to delay ripening and prolong their shelf-life [17].

To our knowledge, has not been much scientific literature cover the applying a carrageenan-beeswax coating with the addition of two plasticizers on fresh-cut mangoes to maintain the quality and extend their shelf-life. Therefore, the purpose of this research was to develop edible film with plasticizer treatment and investigate the effect of an edible coating on quality changes in fresh-cut mangoes during refrigerated storage at 6 °C for 6 days.

2. Materials and Methods

2.1. Raw materials

The edible film materials (glycerol, fructose, glucose, and tween 80) were purchased from Brataco-Bandung, carrageenan from Setiaguna-Bogor, and beeswax from Bees Nature-Tangerang. Mangoes (*Mangifera indica L.*) were used for this study obtained from a traditional market in Subang. Uniformity in size, color, shape, and absence of damage became parameters in the selection of samples.

2.2. Edible film and fresh-cut mangoes preparation

Film solution was prepared by dissolving carrageenan powders in distilled water while stirring and heating at 70-80 °C until the solution became clear. The melting wax of 0.1% (w/v) and tween 80 of 0.2% (w/v) were added into solution. Two plasticizers were used, i.e., glycerol of 1% (w/v) and a monosaccharide of 1%. Two types of monosaccharides were chosen as treatments, i.e., glucose and fructose. The film-forming solutions (85ml) was poured onto acrylic plate 20x20 cm^2 and dried at 50 °C for 24 hours in a cabinet dryer [18].

Mangoes were washed in tap water then peeled manually used a stainless-steel knife and cut in pieces sized about 3 x 3 cm. Fresh-cut mangoes were dipped in film solutions for 1 minute. Samples allowed standing at room temperature (27 °C) for 15 minutes, placed into styrofoam, and then over-wrapped with cling wrap. Fresh-cut mangoes without coating were used as the control. All samples were stored at 6 °C for 6 days

2.3. Analyses of edible film

Measurement of edible film thickness and water vapor transmission rate based on the method described in [19], while solubility described in [20]. Thickness was measured using a hand micrometer (Mitutoyo) with to the nearest 0.001 mm at five random positions around the film, and the average values were used in the calculation.

Water vapor transmission rate was determined by sealing the top of a cup containing silica gel of 10g. Cup was placed in a desiccator containing saturated magnesium nitrate solution (50% RH) at 25 °C. The cup was weighting every day (24 h) over 6 days. The WVTR was calculated by dividing slop of weight to sample.

Film solubility was evaluated by cutting film (diameter 2 cm). The film was weighed, immersed in 50 mL of distilled water, and then periodically agitated during 24h at 25 °C. The dry mass content of initial and final samples was measured by drying the samples at 105 °C for 24h.

2.4. Analysis of Fresh-Cut Mangoes

In order to determine weight loss, samples were prepared in individual packs. The initial weight of the sample was weighed at the beginning of the experiment and observation on days 2, 4, and 6 of storage. Weight loss was expressed as a percentage loss of the initial total weight [15].

The pH of mango puree was measured using a pH meter (Mettler Toledo FE20), while total soluble solids were measured using a digital refractometer (Hand-Held Refractometer ATAGO PAL-1). Fruits were cut into small pieces and pulped using a hand-held blender. Analysis of total acidity was done by adding 100 ml distilled water into 5 g mango puree. This solution then was titrated using NaOH solution with normality 0.1 N. Total acidity was represented in g of citric acid per 100 g of sample. The equation was used to calculate total acidity as follow [21]:

$$Titratable\ acidity = \frac{V_{NaOH} \times N_{NaOH} \times 0.064}{W_{sample}} \times 100\% \quad (1)$$

Where
W_{sample} : the mass of the fruit sample taken for analysis (g)
V_{NaOH} : the ml of NaOH used for titration (ml)
N_{NaOH} : the normality of NaOH solution (N)
0.064 is the conversion factor for citric acid

For the microbiological analysis, fresh-cut mangoes (5 g) crushed using a blender, and then put into 45 ml Buffered Peptone Water (Merck, Germany) aseptically. Sample homogenized using a vortex and dilution. To calculate the total plate count, the sample has been diluted was transferred into Plate Count Agar (Merck, Germany) using the pour plate method, and then, incubation occurred at 37 °C for 48 h. Three samples in each group were analyzed and reported as log CFU/g (colony forming units per g of sample) [22].

Sensory analysis was conducted by 30 untrained panelists to give the score in term taste, flavor, color, firmness and overall liking using a seven-point hedonic scale (1-dislike very much, 2-dislike moderately, 3-dislike slightly, 4- neither like nor dislike, 5-like slightly, 6-like moderately, 7-like very much). The samples were evaluated at day 0.

2.5. Statistical *Analysis*

The experimental design in this research uses a completely randomized design. When analysis of variance (ANOVA) revealed a significant effect (at the 0.05 level), treatment means were compared using Duncan's multiple range test.

3. Result and Discussion

3.1. Edible film characteristics

An important property for effective food packaging is its ability to prevent or minimize moisture transfer between the food and the surrounding environment. Some parameters of edible film related this function are thickness, water vapor transmission rate (WVTR) and solubility and presented in Table 1.

Table 1. Edible film parameters

Plasticizers	Thickness, mm	WVTR, $g/mm^2/day$	Solubility, %
Glyerol	0.048^a	12.61^a	58.99^a
Glycerol-fructose	0.078^b	23.27^b	77.96^a
Glycerol-glucose	0.076^b	22.55^b	77.84^a

Same letters within a column indicate no significant differences among treatments ($p > 0.05$)

Edible films with two plasticizers were significantly higher in thickness, and water vapor transmission rate (WVTR) compared to the film with the single plasticizer ($p <0.05$). The addition plasticizer concentration increases the film thickness, due to the increase in total solids in the film solution. The interstitial distance between the polymer chains in the film matrix could be increased because of the dispersion of plasticizer molecules in the film matrix, which could contribute to the increase in film thickness [23]. A film thickness with an inversion sugar plasticizer was between 0.04 mm and 0.12 mm [24]. Edible films prepared from semi-refined kappa-carrageenan (SRC) plasticized with glycerol or sorbitol at 20, 25, and 30% (w/w) had thickness ranged 0.066 – 0.079 mm

The increase in WVTR can be attributed to the hydrophilic nature of the plasticizer. Similar results were reported by some studies [18, 25], increased hydrophilic plasticizer concentrations lead to reorganization of polysaccharide tissues and an increase in free volume and segmental movement, allowing water molecules to diffuse more easily and provide higher WVTR.

The solubility of films were not significant differences between samples ($p >0.05$). Edible film made with two plasticizers generated solubility higher than mono plasticizer film. Edible film prepared with cassava starch of 5% (w/v) and glycerol of 1.5% (w/v) gave solubility of 73% [26]. Higher concentrations plasticizer resulted in more water-soluble films because plasticizer is hydrophilic. The interaction of plasticizer with the film matrix by increasing the space between the chains, facilitates water migration into the film and, consequently, increasing solubility [27].

3.2. Fresh cut-mangoes quality

3.2.1. Weight loss

Fruit weight loss was mainly related to loss of water and other volatile components in the respiration process and transpiration (water release in the form of water vapor) during storage. The result indicated that the composite layer could inhibit weight loss of fresh-cut mango (Figure 1).

All sample treatments showed a continuous weight loss during the storage period. The weight loss of control (uncoated mango slices) was greater than coated mango slices. The edible coating on fruits could make weight loss is relatively low because the edible coating has the ability to prevent the loss of water in the fruits. A significant difference between control and coated samples was observed at the $p < 0.05$ level when fruit was stored for six days at 6°C. However, there was no significant difference between fruit treated with a type of plasticizer ($p>0.05$). At the end of storage, the weight loss of coated samples with plasticizer glycerol, glycerol-fructose, and glycerol-glucose were 14.34%, 12.47%, and 14.81%, respectively, whereas the uncoated sample had 17.15% loss in weight. The results are consistent with previous studies in which coating based chitosan was found to be effective for delaying weight loss in fresh-cut mangoes [3,15,21] revealed that addition beeswax as a component in the composite coating exhibited a higher reduction in the weight loss of fruit.

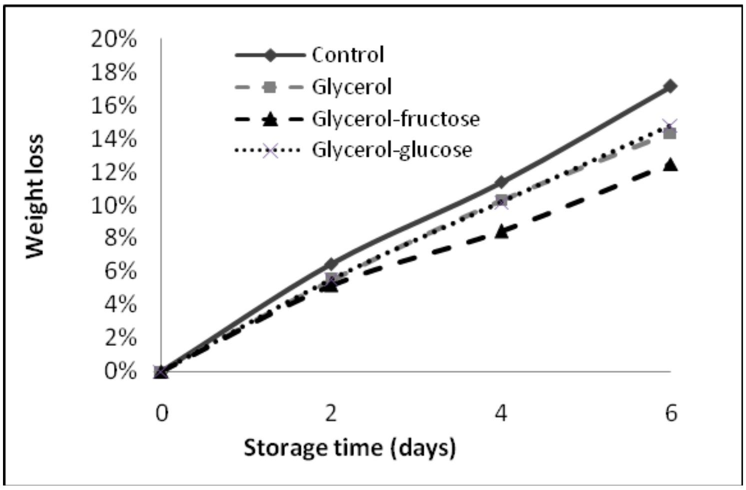

Figure 1. Weight loss value of fresh-cut mangoes stored at 6 °C

3.2.2. pH and total acidity

Generally, some indicators of fruit ripening and tend to increase upon ripening are pH and total acidity. The pH values of uncoated and coated samples during storage were presented in Table 2 and total acidity on figure 2. The initial pH value of an uncoated sample of 3.89 decreased during storage, resulting in a significant difference in storage days 2, 4, and 6, while the coated samples were no significant differences among the pH value of the variously coated samples during the storage period.

Table 2. Change in pH of fresh-cut mangoes during stored at 6 °C

Time (days)	pH			
	Control	***Glycerol***	***Glycerol fructose***	***Glycerol glucose***
0	3.89^{Aa}	3.97^{Aa}	$3{,}99^{Aa}$	3.92^{Aa}
2	3.56^{Ab}	3.97^{Ba}	3.97^{Ba}	3.91^{Ba}
4	3.41^{Ab}	$3{,}97^{Ba}$	3.98^{Ba}	3.94^{Ba}
6	3.38^{Ab}	3.96^{Ba}	3.99^{Ba}	3.93^{Ba}

Same capital letters within a row and same small letters within a column indicate no significant differences among treatments ($p > 0.05$)

After six days of storage, the pH of uncoated sample was 3.38, and for coated sample of 3.96; 3.99; and 3.93 for composite coating with plasticizer glycerol, glycerol and fructose, and glycerol and glucose, respectively. There was no significant difference among the pH value of fresh-cut mango coated with chitosan and dextrin after 6 days storage at 4 °C [28].

The result showed that the total acidity of coated samples no significant differences during storage, while the uncoated samples were significant differences at 2, 4, and 6 days. After 6 days of storage, the total acidity of coated samples was 0.49%, 0.49%, and 0.57%, while the uncoated sample was 0,80%, respectively (figure 2). The total acidity of chitosan-coated and uncoated mango fruit was not significantly different ($p>0.05$) after 7 days of storage, indicated that chitosan coating did not affect the total acidity of samples [15]. During storage, the total acid of fruit increased because of physiological process of the fruit itself and fermentation process resulting in organic acid. By serving as a gas barrier, the edible coating could act to control metabolic reaction and delayed respiration process. The surface coating could increase the resistance of fruit surface to gas permeability, reducing the respiration rate, and creating a modified internal atmosphere [29].

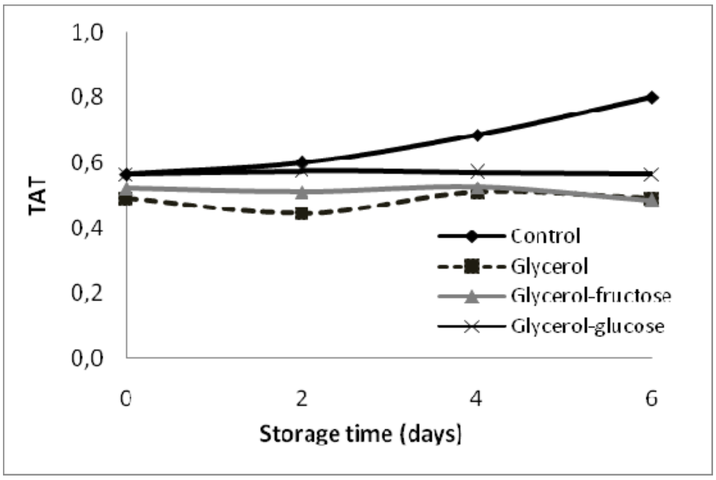

Figure 2. Total acidity value of fresh-cut mangoes stored at 6 °C

3.2.3. Total soluble solids

Changes in the total soluble solids of uncoated and coated fresh-cut mango over the storage period are shown in Figure 3.

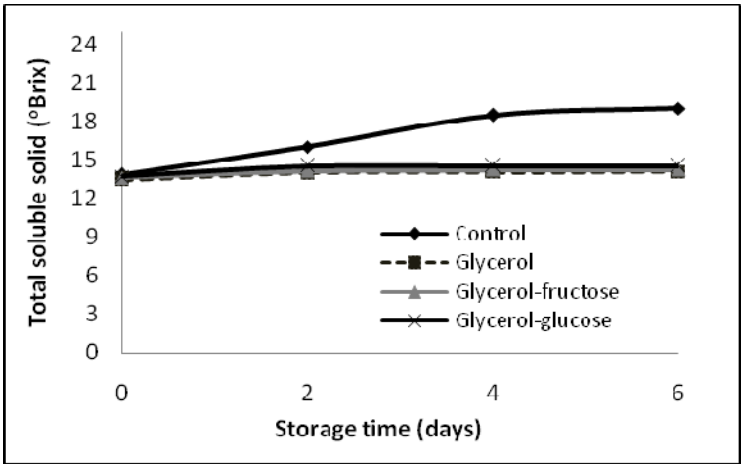

Figure 3. Total soluble solid value of fresh-cut mangoes stored at 6 °C

Fresh-cut mango slices that were not coated contained higher total soluble solids than coated mango slices. The soluble solids content of coated samples remained constant until the sixth day of storage and showed no significant difference (p>0.05) among the treatments. Only the soluble solid content of the control sample was higher and differed significantly from the rest of the fruits. At 0 and 2 days storage time, the total soluble solids content of uncoated samples was not significantly different (p>0.05), but at 4 and 6 days storage, there was a significant difference. The increase total soluble solid of fruit could be caused a lot of water loss during storage and acid metabolism as a result of fruit ripening still continuous by converting starch and acid to sugar [21; 30]. The metabolic activity involving oxygen from the environment will accelerate the ripening of fruit. The edible coating showed the ability to retain an increase total soluble solids of fresh-cut mango because edible coating could withstand oxygen transfer from the environment.

3.2.4. Microbiological analysis

In the preservation of minimally processed food, one of the most important factors to be considered is microbial safety. The microbiological analysis of coated and uncoated fresh-cut mangoes was presented in Table 3.

Table 3. Change in microbial counts of fresh-cut mangoes during stored at 6 °C

Time (day)	**Microbial counts (Log CFU/g)**			
	Control	**Glycerol**	**Glycerol fructose**	**Glycerol glucose**
0	2.74^{Aa}	2.54^{Ba}	2.08^{Ba}	2.11^{ABa}
2	5.90^{Aa}	3.11^{Ba}	2.78^{Ba}	5.85^{ABa}
4	5.94^{Aa}	3.64^{Ba}	3.42^{Ba}	6.77^{Aa}
6	7.09^{Ab}	3.30^{Ba}	4.36^{Ba}	6.49^{Ba}

Same capital letters within a row and same small letters within a column indicate no significant differences among treatments (p > 0.05)

The growth of microorganisms on control (uncoated samples) significantly increased after storage 6 days (p≤0.05). The total plate count of control (uncoated samples) at the end storage increased from 2.74 to 7.09 logs CFU/g. The carrageenan-beeswax coating on the fresh-cut mango effectively inhibited the growth of microorganisms. Nevertheless, the type of plasticizer did not further affect the growth of microorganisms (p>0.05). Microorganisms need oxygen to grow. The edible coating could withstand oxygen transfer from the environment, so decrease the risk of microorganism growth. The result was in accordance with previous studies [3; 15] which reported that the application of chitosan to sliced and fresh-cut mango respectively, could inhibit the growth of microorganisms.

The Indonesian National Standard (SNI 7388: 2009) concerning the maximum limit of microbial contamination in food for wet fruit sweets gives the total plate count limit (30 °C, 72 hours) of $1x10^5$ colonies/g. The control treatment showed that fresh-cut mangoes had exceeded the permitted standard threshold on the second day, as well as the glycerol-glucose treatment. In the treatment of glycerol plasticizer and glycerol-fructose plasticizers, they were below the maximum threshold for microbial contamination until the sixth day.

3.2.5. Sensory evaluation

Sensory data for fresh-cut mangoes are presented in Table 4. Five characteristics of mango (taste, flavor, color, firmness and overall liking) were analyzed for acceptability.

The odor, the color, and the firmness scores of control and coated mangoes were not significantly different (p>0.05). The edible coatings covered the fruits are transparent and thin, so they do not show significant differences. There were significant differences (p≤0.05) in the taste and the overall liking scores of mango fruit coated by glycerol-fructose with other treatments. The taste, the odor, the firmness, and the overall liking of uncoated fresh-cut mango received the highest score. It could be explained that the possibility of some ingredients of edible coating decreased the sweetness, resulted in a particular odor, and increased the hardness of treated samples. In term of color, coated mango received the better score, related with the glossy coating. The sensory quality deterioration of peeled litchi fruit could be delayed by coating used chitosan [31]. Chitosan coatings could preserve fresh-cut mango quality by maintaining sensory attributes in visual appearance, firmness and overall liking [15].

Table 4. Sensory quality of fresh-cut mangoes during stored at 6 °C

Attribute	**Control**	**Glycerol**	**Glycerol fructose**	**Glycerol glucose**
Taste	4.77^{b}	4.30^{ab}	4.00^{a}	4.67^{b}
Odor	4.33^{a}	3.90^{a}	3.80^{a}	4.17^{a}
Color	4.53^{a}	4.83^{a}	4.30^{a}	4.40^{a}
Firmness	4.73^{a}	4.27^{a}	4.23^{a}	4.50^{a}
Overall liking	4.57^{b}	4.40^{b}	3.90^{a}	4.43^{b}

a-b means within a column with different letters are significantly different (p≤0.05)

4. Conclusion

The combination of plasticizers utilized in the carrageenan-based edible films had remarkable effects on increasing thickness, water vapor transmission rate (WVTR), and solubility compared to the film with the single plasticizer. This edible coating could prolong fresh-cut mangoes during storage at 6 °C for 6 days. The edible coating could reduce weight loss, maintain pH and total acidity, delaying an increase of total soluble solids, and retard the growth of microorganisms in fresh-cut mangoes. In addition, there was not different in sensory perception between the coated fruit compared to the uncoated fruit.

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