MANGOSTEEN-AIM

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Research article

Nano-ecogel to maintain the physicochemical characteristics of fresh-cut mangosteen

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Abstract: Fresh-cut mangosteen is a minimally processed product that is currently popular due to the requirement for fresh produce, quality, convenience, and minimal preparation. The process of skin removal causes fast deterioration in fresh-cut mangosteen. The nano edible coating of aloe vera gel or nano-ecogel can be applied to delay physicochemical changes in fresh-cut mangosteen. This study is intended to determine the effect of nano-ecogel concentration and immersion time to maintain the physicochemical characteristics of fresh-cut mangosteen. The effects of the concentration of nano-ecogel (100%, 75%, 50%, and 25%, *v*/*v*) and immersion time (1, 2, and 3 min) of fresh-cut mangosteen on acidity, vitamin C, water content, total dissolved solids, weight loss, texture and browning index were evaluated for nine days of cold storage. The concentration of nano-ecogel, immersion time, and interaction affected the acidity, water content, total dissolved solids, weight loss, and browning index of fresh-cut mangosteen. The best treatment was immersion in 50% nano-ecogel for 1 min.

Keywords: edible coating, mangosteen, nanocoating, physicochemical, shelf-life, fresh-cut, fruit

1. Introduction

Mangosteen is a tropical fruit that is currently popular. The mangosteen fruit has a delicious taste and contains vitamins, minerals, and antioxidants that are beneficial for health [1,2]. Mangosteen is perishable. Although edible parts are still suitable for consumption, damage to nonedible parts, such as skin, determines consumer preferences. The number of nonedible parts of the mangosteen fruit (around 63%–75%) is relatively high and contributes to household waste [3,4], causing a growth in the sales of edible parts, i.e., fresh-cut fruits. The fresh-cut selection is also driven by consumer demand for quality products and a lack of preparation time [5–7].

Fresh cuts are products with minimal processing steps to get maximum quality. Processing includes stripping, cutting, slicing, pith removal, washing, and packaging [8]. Some of the advantages of minimally processed products include providing consumers with a variety of choices in one package, enabling consumers to get the required fresh quantity, easy assessment of quality, and reducing the volume and transport costs [4]. Fresh-cut fruit has the disadvantages of perishability and shorter shelf-life than the whole fruit [5,9]. Tissue injury causes the fruit to undergo physicochemical changes, which induce deterioration [10,11].

According to [5] and [12], the application of 1% $CaCl_2$ combined with cold storage enhances the firmness of fresh-cut and prevents browning. The application of the edible coating helps maintain the freshness of fresh-cut products [13], as a barrier against mass transfer and gas exchange [14]. According to [15], edible coatings improve appearance (bright and shiny colors), retain moisture, prevent weight loss and protect against microorganisms. However, there has been no previous research on the application of the edible coating on fresh-cut mangosteen. Therefore, it is important to study and know the coating method and extend shelf life.

Aloe vera gel has potential as an edible coating (ecogel) because it consists of polysaccharides containing more than 75 functional chemical compounds, such as saponins, sterols, acemannan, vitamins, and folic acid [16]. The advantages of using ecogel are biodegradability, permeable oxygen, antioxidant activity, low toxicity, low cost, and ease of application [17]. The concentration of additives determines the consistency of the ecogel. The optimal concentration of citric acid, ascorbic acid, and potassium sorbate additives is 0.15% [18]. The obstacle in applying ecogel to fresh-cut fruit is the difficulty of adhesion on the surface of hydrophilic fruit slices [5].

The adhesion ability of the ecogel is influenced by the structure, size, and chemical constituents. The small size of the particle improves solubility, absorption of active compounds, and controlled release. The nano-ecogel is one of the applications of nanotechnology in the postharvest handling of fresh-cut fruit. There are many reports of aloe vera for coating fruits and vegetables, but the application of nano-ecogel is a new study. The advantages obtained from the use of nano-ecogel include a barrier, mechanical properties, emulsion system, and bioavailability [19]. The ecogel application is influenced by composition, time, method, and layer thickness. The use of nano-ecogel is an effort to maintain the physicochemical change in fresh-cut mangosteen [19,20]. However, to the best of the authors' knowledge, no information is available on the concentration of nano-ecogel and the best immersion time of fresh-cut mangosteen. Therefore, research is needed to determine the concentration of nano-ecogel and immersion time to maintain the physicochemical characteristics of

fresh-cut mangosteen.

2. Materials and method

2.1. Preparation of nano-ecogel

Preparation of nano-ecogel using the method invented by [18]. The first step of ecogel production is sorting 1-year-old aloe leaves (*Aloe barbadense*. Miller). Leaves were left for 24 h at room temperature to remove yellow mucus. Aloe leaves were washed with water to remove the yellow mucus residue and unpleasant odors that could reduce the quality of the gel. Tripping and filleting were to produce gel fillets by using a stainless knife. Gel filets were homogenized for 5 min and heated at 70 ± 1 °C for 5 min [21]. The gel was cooled for 1 h at 27 °C and filtered with the Rocker 300 vacuum pump, 5340FK1000R flash filter, and Whatman filter paper no. 42. Aloe gel was added with a mixture of citric acid, ascorbic acid, and potassium sorbate with concentrations of 0.15% (*w/v*). The agitation process used the sonicate masonic Q125 to obtain the nanostructures, with a 59-time delay pulse of 30 seconds for 50 min. The size of ecogel nanoparticles was determined using the UV–vis spectrophotometer. The maximum absorbance indicated a particle size of 20–110 nm [22].

2.2. Preparation fresh-cut mangosteen

Fresh and ripe mangosteen fruits aged 105 days since flowering were collected from a garden in Panji Village, Sukasada District, Buleleng Regency, Bali Province, Indonesia. The criteria of mangosteen fruit included greenish-yellow skin color with 50% pink spots spreading on the skin, round like a compressed ball, flesh consisting of 5–8 segments, fresh green petals, and fruit weight of 130–180 g. The mangosteen fruit was precooled by washing with water and stored in a clean tissue paper to drain excess water. The mangosteen fruit was peeled carefully to obtain a fruit without skin (fresh-cut fruit) and left with fused segments.

2.3. Ecogel application

Peeled fresh-cut mangosteen was first dipped into 1% $CaCl_2$ solution for 10 min and dried using a blower for 20 min. Fresh-cut mangosteen was applied with 100%, 75%, 50% and 25% nano-ecogel. A concentration of 100% nano-ecogel meant pure nano-ecogel, whereas 75% concentration indicated 75 mL nano-ecogel and 25 ml water. The immersion time of fresh-cut mangosteen in the nano-ecogel was 1, 2 and 3 min. This study was repeated three times. Fresh-cut fruits coated with nano-ecogel was drained and dried using a blower for 20 min. Furthermore, fresh-cut mangosteen was packaged in a 10 cm × 20 cm × 5 cm plastic box equipped with two holes with a diameter of 0.5 cm on the lid and stored at a cold temperature (7 ± 1 °C). During storage for 3, 6 and 9 days, acidity [30], vitamin C [31], water content [34], total dissolved solids (TDS) [30], weight loss [23], texture [32], and browning index [33] were evaluated.

2.4. Statistic analysis

This study used a completely randomized design factorial pattern. Statistical analysis was performed using SPSS to measure the variance of all observed variables through analysis of variance. The significant value obtained using Duncan, $p < 0.05$ shows a noticeable difference.

3. Results and discussion

3.1. Acidity

Immature fruits contain some organic acids, which tend to degrade during ripening. A decrease in acidity changes the acidity of the fruit. The acidity of fresh-cut mangosteen after nano-ecogel application on day 3 is on average higher than before application which is 3.06. A high concentration of nano-ecogel results in an increased ability to cover the surface pores of the fruit, thereby inhibiting the process of converting sugar into organic acids [35]. The taste of fruits is mostly influenced by the contents of sugar, organic acids, phenolics, and volatile compounds.

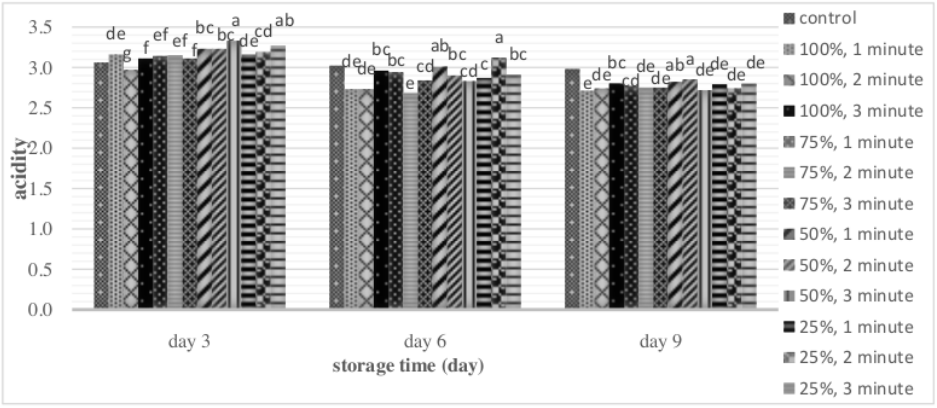

Figure 1. The acidity of fresh-cut mangosteen during cold storage.

High nano-ecogel concentrations caused the fresh-cut surface to close, thus delaying the conversion of sugar into organic acids. In line with the results of the study [35], that the application of nanoparticles chitosan inhibits the conversion of starch to sugar and sugar to organic acid, due to the ability of this coating as a barrier in the surface of fresh-cut. The nanostructured edible coating on minimally processed foods effectively controlled moisture loss and retained the color and extend shelf-life of apple slices [36]. Following the opinion of [23], aloe vera gel contains many functional components, and antimicrobials and antioxidants can inhibit postharvest damage.

3.2. Vitamin C

Fresh-cut mangosteen stored for nine days and treated with 50% nano-ecogel has the highest vitamin C content. Figure 2 shows that the fresh-cut mangosteen fruit on day 3 was treated with 50%

nano-ecogel, the highest vitamin C content (2.79 mg/100 g), 25% ecogel the lowest vitamin C content (2.27 mg/100 g). This means 50% is the most ideal concentration of nano-ecogel coating solution to cover the pores of the fresh-cut surface so that the vitamin C oxidation process can be avoided. The vitamin C content of fresh-cut mangosteen on days 6 and 9 ranges from 1.68 mg/100 g to 2.22 mg/100 g and from 1.55 mg/100 g to 1.89 mg/100 g, respectively. The mangosteen fruit contains several important nutrients, including xanthones and vitamin C [24,25], and their amounts are remarkably influenced by many factors, e. g. variety, environment, and maturity. Vitamin C levels in fresh-cut mangosteen are relatively stable, indicating that the application of nano-ecogel can maintain the vitamin C levels of fresh-cut mangosteen. The loss of vitamin C in the material is due to the oxidation process [26]. Aloe vera gel has antioxidant abilities that can inhibit postharvest damage [27].

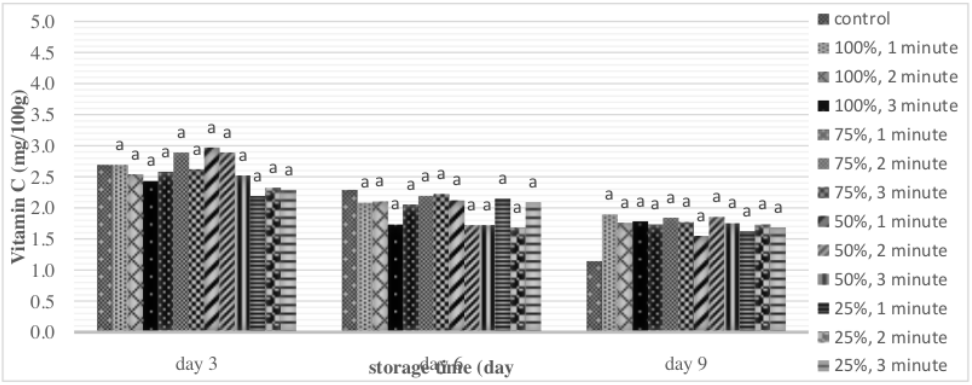

Figure 2. Vitamin C (mg/100g) of fresh-cut mangosteen during cold storage.

3.3. Water content

The decrease in the water content of fresh-cut mangosteen is unavoidable. Mangosteen is a climacteric fruit that still undergoes respiration, i. e. carbohydrates are broken down into simple sugars, water, and energy [1]. Increasing the concentration of nano-ecogel can suppress water loss. A previous study [5] showed that the application of edible coating retains water and results in bright and shiny colors. Edible coatings on the fruit surface tissue aim to modify the environment, inhibit gas transfer, reduce water and aroma loss, change color and improve the appearance [28]. Fresh-cut mangosteen has the highest water content on the ninth day by a nano-ecogel concentration of 100% for 3 minutes, and the lowest on 25% nano-ecogel for 3 minutes. Water loss can be suppressed by increasing the concentration of nano-ecogel. [28] stated that edible coating on the surface of fresh-cut fruit aims to modify the atmosphere, inhibit gas transfer, lose water and aroma, delay color change, and improve appearance. Aloe vera gel consists of polysaccharides glucomannan and acemannan which have potential as edible coatings on fruits [18]

Table 1 shows no significant result in terms of different days at various treatments. The moisture contents of fresh-cut mangosteen fruit are 80.43%–84.45%, 80.82%–83.63%, and 80.47−87.10% on days 3, 6, and 9, respectively. The high concentration of nano-ecogel delays the

loss of water of fresh-cut mangosteen. Aloe vera gel consists of glucomannan and acemannan polysaccharides, which have the potential as edible coatings and prevent water loss in fruits [27].

Table 1. Water content (%) of fresh-cut mangosteen during cold storage.

Concentration of Ecogel	Immersion time (minutes)	Day		
		3	6	9
Control		81.45	82.91	82.35
100%	1	82.73 b	81.57 f	81.93 g
75%	1	82.16 g	81.10 i	80.47 i
50%	1	81.72 i	81.32 h	82.02 f
25%	1	81.96 h	81.73 e	81.95 g
100%	2	84.45 a	83.63 a	85.15 b
75%	2	82.64 c	81.80 d	83.33 c
50%	2	82.33 f	82.46 c	81.15 h
25%	2	81.54 j	81.57 f	82.30 e
100%	3	82.46 d	83.40 b	87.10 a
75%	3	80.43 e	81.60 f	83.62 c
50%	3	82.64 c	79.50 g	82.41 d
25%	3	81.12 k	80.82 i	79.98 j

Note: Different letters behind the average value in the same column showed a significant difference with Duncan's test 5%

3.4. TDS

The application of nano-ecogel at a high concentration on day 3 leads to increased TDS of fresh-cut mangosteen because mangosteen is a climacteric fruit and still ripens during storage. Several types of sugar glucose, fructose, and sucrose in climacteric fruits, such as mangosteen, tend to increase during cell maturation [29]. The nano-ecogel concentration of 50% can maintain the TDS of fresh-cut mangosteen fruit on days 6 and 9. Table 2 shows that the highest total soluble solids of fresh-cut mangosteen fruit (24.82 °Brix) is obtained at immersion in 50% ecogel for 3 min. The nano-ecogel concentration of 50% produces a solution that is not too thick and also does not dilute. In line with the opinion [13] that a good coating solution is non-sticky and easily dry. TDS remain stable because the application of nanoparticles inhibits the conversion of sugar to organic acid, due to the ability as a barrier in the surface of fresh-cut [35]. The lowest TDS is 23.42 °Brix and observed at immersion in 25% ecogel for 1 min. Fresh-cut mangosteen fruit on day 6, a TDS value between 22.22 °Brix and 23.82 °Brix. On the ninth day of storage, fresh-cut mangosteen immersed at 50% ecogel for 3 min has the highest TDS (24.02 °Brix), and that immersed at 100% ecogel for 2 min has the lowest TDS (20.02 °Brix). The application of ecogel on the fruit surface has the advantage of several active ingredients that can be inserted into the polymer matrix for the maintenance of freshness and sensory attributes [30]. Results from a previous study [17], showed that aloe vera gel can be used to extend shelf life and maintain freshness at cold temperatures.

Table 2. Total dissolved solids (°Brix) of fresh-cut mangosteen during cold storage.

Concentration of Ecogel	Immersion time (minutes)	Day		
		3	6	9
Control		23.50	22.70	22.60
100%	1	23.62 de	22.32 d	22.02 c
75%	1	24.12 cd	23.12 b	21.42 f
50%	1	24.12 cd	23.12 b	21.92 cd
25%	1	23.42 e	22.42 cd	21.72 e
100%	2	23.82 de	22.22 e	20.02 h
75%	2	24.82 a	22.22 e	21.82 de
50%	2	23.52 e	21.32 d	20.72 g
25%	2	23.82 de	22.72 c	21.82 de
100%	3	24.52 ab	23.82 a	21.82 de
75%	3	24.22 bc	22.52 cd	22.32 b
50%	3	24.62 ab	23.82 a	24.02 a
25%	3	24.32 bc	22.42 cd	21.82 de

Note: Different letters behind the average value in the same column showed a significant difference with Duncan's test 5%

3.5. Weight loss

A high concentration of nano-ecogel and long immersion on days 3, 6, and 9 results in a high possibility of closing the pores of the fresh-cut mangosteen surface, thereby suppressing transpiration and decreasing weight loss. Following the opinion of [31], edible coatings can retain moisture and prevent weight loss. The highest fresh-cut mangosteen weight loss at immersion in 25% nano-ecogel for 3 min is significantly different from those at other treatments. The lowest weight loss is observed at immersion in 100% nano-ecogel for 3 min. Figure 3 shows that the highest weight loss of fresh-cut mangosteen 3.83% (FW) is obtained at immersion in 25% ecogel for 3 min and that the lowest weight loss of fresh-cut mangosteen 0.51% (FW) is observed at immersion in 100% ecogel for 3 min. The fresh-cut mangosteen fruits on days 6 and 9 have weight loss values of 0.52%–6.54% and 0.52%–6.54% (FW), respectively. Aloe vera gel, as a protector against physical and chemical biological changes, is reported to form a thin layer, improve appearance, and retain moisture [17]. The weight loss of fresh-cut mangosteen increases until the end of storage, which is day 9. Given that fresh-cut mangosteen has a climacteric pattern, the respiration rate still increases during storage [4]. Fresh-cut mangosteen after the nano-ecogel application shows a lower weight loss than that before the nano-ecogel application.

3.6. Texture

The texture of fresh-cut mangosteen was measured using a texture analyzer at a speed: distance of 10:8. Texture changes during the storage period of fresh-cut mangosteen occur due to the ripening process, and the fruit that is stored for a long time softens because of the influence of pectolytic enzymes. The highest texture value of fresh-cut mangosteen until day 9 is obtained at immersion in 50% nano-ecogel for 1 min. The lowest texture is obtained at immersion in 25% nano-ecogel for

1 min. Table 3 shows that the texture values of fresh-cut mangosteen on days 3 and 6 are 1.58–3.56 and 1.51–3.07 N/m, respectively. The highest texture of fresh-cut mangosteen on day 9 (2.89 N/m) is obtained at immersion in 50% ecogel for 1 min. The lowest texture of 1.38 N/m is obtained at immersion in 25% ecogel for 1 min. This result shows that immersion in 50% nano-ecogel for 1 min can maintain the fresh-cut texture of mangosteen. [2] stated that fruit texture decreases during storage. The activity of pectinase during storage automatically causes loss of rigidity in the fruit tissue [14]. The nano-ecogel interacts with pectin polymers to form crosslinking networks that increase mechanical strength, which delays senescence and controls physiological damage of fresh-cut mangosteen.

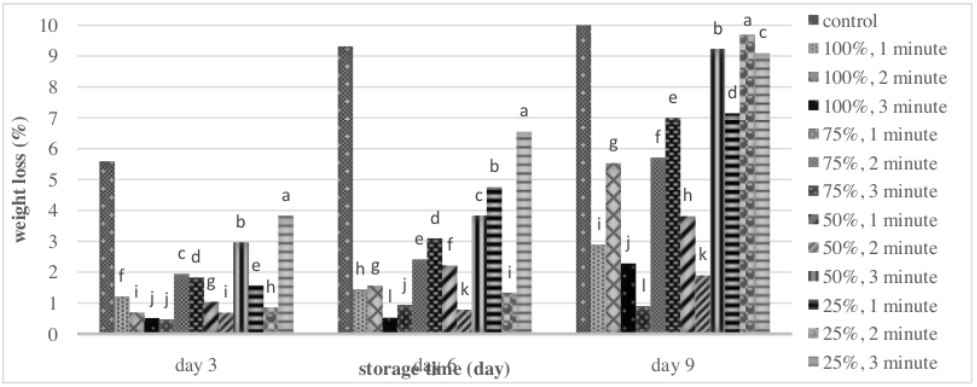

Figure 3. Weight loss (%) of fresh-cut mangosteen during cold storage.

Table 3. Texture (N) of fresh-cut mangosteen during cold storage.

Concentration of Ecogel	Immersion time (minutes)	Day		
		3	6	9
Control		1.20	0.83	0.60
100%	1	3.01 a	2.76 a	2.65 ab
75%	1	2.44 a	2.15 a	1.66 cd
50%	1	3.08 a	3.00 a	2.89 a
25%	1	3.25 a	3.07 a	1.38 d
100%	2	3.56 a	1.94 a	1.83 cd
75%	2	2.49 a	2.80 a	2.79 a
50%	2	2.53 a	1.95 a	2.19 cd
25%	2	1.59 a	1.88 a	1.86 cd
100%	3	2.15 a	1.51 a	1.42 d
75%	3	2.60 a	2.78 a	2.36 bc
50%	3	1.84 a	1.62 a	1.77 cd
25%	3	1.58 a	1.70 a	1.78 cd

Note: Different letters behind the average value in the same column showed a significant difference with Duncan's test 5%

3.7. Browning Index

The lowest browning index of fresh-cut mangosteen on day 3 of 1.99 is observed at immersion in 100% nano-ecogel for 3 min. Figure 4 shows that the highest browning index of fresh-cut mangosteen on day 3 is 8.18, which is obtained at immersion in 25% ecogel for 3 min. The highest browning index on day 6 ranges from 1.01 to 8.34. Observations on day 9 show that the highest browning index is 32.62 and observed at immersion in 100% ecogel for 3 min and that the lowest browning index is 9.88 and observed at immersion in 50% ecogel for 1 min. This result indicates that increasing the concentration of nano-ecogel at the same immersion time results in reduced browning of fresh-cut mangosteen. Nano-ecogel at the right concentration and immersion time will produce a layer that can cover the fresh-cut surface perfectly and contact with oxygen was avoided. Thus, the browning reaction can be prevented. If the fresh-cut surface is tightly closed, the addition of immersion has no effect. [28] stated that edible coating on the surface of fresh-cut fruit aims to modify the atmosphere, inhibit gas transfer, delay color change, and improve appearance.

The enzymatic oxidation of monophenols produces *o*-diphenols, which are converted into quinones. Nonenzymatic polymerization forms the brown or melanin color [9]. The ability of nano-ecogel as an antioxidant can inhibit the oxidation process of phenol compounds and postharvest damage [27]. Day 6 also shows the same results as day 3, the immersion of fresh-cut mangosteen in 50% nano-ecogel for 1 min has provided a low browning index of 4.87 than control of 8.30. On day 9, the treatment of 50% nano-ecogel for 1 min has provided a low browning index of 27.83 than control 29.10. Several researchers applied aloe vera gel with concentrations ranging from 50% to 100% as an edible coating to preserve whole fruits, such as table grapes [32], mango [33,37], blueberries [34], and apricot [35,38].

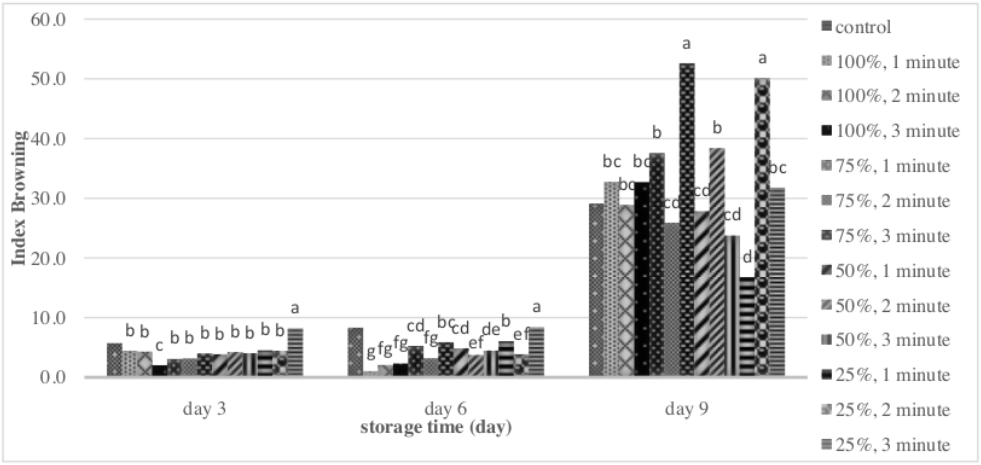

Figure 4. Browning index of fresh-cut mangosteen during cold storage.

Figure 5. The appearance of fresh-cut mangosteen after application of nano-ecogel on the 9th day of storage.

4. Conclusions

The effects of nano-ecogel concentration, immersion time, and their interaction on the degree of acidity were investigated. In addition, the water content, TDS, weight loss, and browning index of fresh-cut mangosteen were studied. In conclusion, immersion in 50% nano-ecogel for 1 min maintained the freshness of fresh-cut mangosteen. Compared with the initial fruit, the fresh-cut mangosteen after nano-ecogel application was more attractive, whiter, juicy, and shiny until the ninth day of storage.

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