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Maintaining physicochemical and sensory properties of guava var. Getas Merah using alginate and *Cyclea barbata* leaves powder as edible coating

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Abstract: Indonesia is one of the major countries which contributes the world's guava production. Guava var. Getas Merah is commonly found in Indonesia. Guava has a short shelf-life as it rapidly goes under postharvest ripening. This leads to a faster deterioration of physicochemical and sensorial properties of guava. A generally used method to extends shelf-life is by edible coating. In this study, a combination of alginate and *Cyclea barbata* leaves powder (CBLP) was investigated as a potential edible coating. The analysis of firmness, total soluble solids, total reducing sugar, total titratable acidity and organoleptic tests were conducted to evaluate the quality of guava fruits stored for 20 d at 14°C. A split plot design study was used and four different treatments with different CBLP concentrations were applied. The samples treated with 2% alginate and 0.8% CBLP showed the lowest total dissolved solids, total reducing sugar, and total titratable acidity. Moreover, the samples were reported with the highest score on color, taste, and texture parameters. The firmness test showed that samples treated with 2% alginate and 0.2% CBLP had the lowest firmness loss and highest score for aroma. In summary longer quality retention of guava fruits was found after the addition of CBLP in alginate-based edible coating.

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1. Introduction

As a tropical country, Indonesia is rich in horticultural products, especially fruits. Guava (*Psidium guajava L.*) var. Getas Merah is one of many fruits that are highly produced and consumed in Indonesia. Although it has high content of vitamin C, dietary fiber, antioxidants, and minerals, guava is a perishable food product and has a relatively short shelf life (Kumar *et al*., 2001; Naaseer *et al*., 2018). During its ripening stage, guava undergoes physicochemical changes such as total soluble solid, pectin content, total titratable acidity, total sugar content, and total anthocyanin content (Dube and Singh, 2015). Total soluble solids of guava cv. Apple

Colour were found to be increasing rapidly between 75 to 150 days. Whereas its maximum acidity of 0.41% was reached after 105 days. Following the increase of total titratable acidity during immature and intermediate stage of maturation, the value will be decreased during maturity stage. On the contrary, total reducing sugar increased during late maturity. These changes happen very fast; therefore, fully ripe guava can easily bruise and considered as highly perishable (Fabi *et al.*, 2010). By reducing the rate of this physicochemical and sensory properties to sustain the quality of guava, shelf-life extension can be achieved.

The storage of guava with chemicals such as boric acid and naphthalene acetic acid (NAA) at ambient temperature is commercially available and feasible (Singh *et al.*, 2017). Although this technique has been proven to effectively maintain the quality of guava, the use of chemicals may affect those potential consumers that have a negative perception of chemical preservatives. The use of plastic packaging for individual packaging with clink and shrink film was reported (Rana *et al.*, 2015). By individually wrapping guava fruits, changes of total soluble solids slowed down and extending the shelf life for 10 days. However, the use of plastic is not a sustainable choice.

The preservation technique by edible coating can be an option for a more sustainable choice. It is applied by adding a thin layer to the fruit to prevent gas release. The edible coating must be able to form a layer that acts as a respiration and transpiration inhibitor by reducing moisture and solute migration and gas exchange. Another requirement for edible coating material is that it is safe to consume and has the ability to enhance shelf-life (Vaishali *et al.*, 2019). Compared to the synthetic coatings, edible films can act as both gas and moisture barrier which results in a modified atmosphere to enhance the shelf life of fruits (Kocira *et al.*, 2021). Polysaccharides such as alginate, chitosan, and pectin, are the most frequent polymer used for edible coatings. Alginate is derived from brown sea algae and is an example of hydrocolloids, film-forming biopolymers (Parreidt *et al.*, 2018). The application of alginate-based edible coatings has been conducted with the addition of various ingredients to extend the shelf life of guava. The application of alginate and betel-essential oil on rose apple resulted in quality retention until nine days (Setiawan *et al.,* 2019). The effect of both chitosan and alginate edible coating with the addition of pomegranate peel extract were reported (Nair *et al.*, 2018). The study reported significant retention of quality deterioration in guava after the edible coating's application and storage at 10°C. Another study by showed that the addition of ZnO nanoparticles in chitosan and alginate effectively inhibits rot in guavas, indicating their antimicrobial action (Arroyo *et al.*, 2020).

In this study, *Cyclea barbata* leaves, which also has potential as an edible coating, is economically feasible, and is more available in Indonesia, was included to the alginate coating. *Cyclea barbata* is a well-known plant that is widely used by Indonesian people as food and medicine. It is rich in carbohydrates, polyphenols, saponin, calcium, phosphor, and vitamins A2 and B (Acamovic and Brooker, 2005). The main component of *Cyclea barbata* leaves extract that forms a gel is pectin polysaccharide with low methoxy content belongs to the gel-forming hydrocolloid group. The gel formed by pectin will be highly adhesive ~~f~~and transparent and consequently has potential as an edible coating material (Rachmawati *et al.*, 2010). Thus, this study investigated the addition effect of *Cyclea barbata* leaves powder (CBLP) in alginate-based coating as edible coating to maintain physicochemical parameters and sensory quality of guava.

2. Materials and Methods

Study design

This study was conducted using a split plot design study. This study was carried out in 2018 and used four treatments with a variation of CBLP concentrations. A total of 135 whole guava fruits were used during this study. Each treatments used 27 guava that were grouped for each three guavas to be stored in a polystyrene board with plastic wrap after coating as one set. These three pieces of guava acted as triplicates of biological replicates. During the 20 days of storage, physicochemical and sensory analyses were done every four days. During this days, one set of fruits were randomly taken to be analyzed further for its physicochemical properties. Then, one fruit were selected randomly for sensory analyses.

Plant materials

This study used guava from an orchard in Sleman Regency, Yogyakarta, Indonesia. The guava used in this study was harvested 109-114 days after the fruit bloomed. According to a previous study, guava can be harvested after optimum maturity by observation of color attained or between 105-135 days after the fruit sets (Dube and Singh, 2015). This range of day is suitable for distant transportation to refrain from harvest losses. However, the length of the distance from this study was not mentioned. Therefore, this study used a more restricted range of harvesting days.

The fruits were selected by visual observation to remove the defected fruits and choose the fruits with the same size. Then, fruits with a weight of 170 g were selected. From the orchard, selected fruits were transported to Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Indonesia. The fruits were stored in the refrigerator at 14°C for one day; then they were washed by submerging in 0.05% sodium benzoate solution for 10 min and dried to prevent the growth of bacteria and molds during storage (Masamba Mndalira, 2016).

Preparation of CBLP and alginate edible coating

The coating used in this study was produced according to a previous study (Olivas *et al*., 2007), with some modifications. The CBLP was made by cleaning fresh *Cyclea barbata* leaves with water followed by drying (oven-dried) at 50°C for 18 h. The dried leaves were ground and sieved using a sifter (0.5 mm mesh) to produce a powder. Alginate was made by dissolving 10 g alginate in 500 mL water (to make 2% alginate solution) and heating with a water bath at 80°C for 30 min while stirring until the solution became transparent. A total of 2.5% glycerol as a plasticizer was added to the edible coating solution.

The treatments with different formulation used was as below:

- No coating applied (control)
- 2% alginate + 0.2% CBLP
- 2% alginate + 0.4% CBLP
- 2% alginate + 0.6% CBLP
- 2% alginate + 0.8% CBLP

Application of edible coating solution

Selected fruits that had been washed were soaked in the edible coating solution for 3 min, followed by dipping into a 2% $CaCl_2$ solution for 15 min until it formed a layer. The samples were dried at room temperature. Each three samples were stored in a polystyrene board wrapped with plastic. The storage temperature was kept at 14°C and 95% RH.

Analyses of physicochemical parameter

To investigate the ability of shelf-life extension by adding CBLP to alginate coating, the samples were measured for their physical (firmness), chemical (total soluble solids, total reducing sugar, and titratable acidity), and organoleptic qualities. The parameters were measured every four days within 20 d of storage time.

Firmness. The analysis of firmness was conducted by measuring the samples chosen for the weight loss measurements using a penetrometer. The samples with the skin still intact were stabbed with the device in three different locations using 250 g of pressure on the scale of 1/10 mm for 10 s. The results obtained were averaged and expressed in kg/cm^2.

Total soluble solids. The samples for the analysis of total soluble solids were selected by choosing one random guava in a box of nine fruits. The chosen sample was extracted by mashing the fruit and pressing to obtain the juice. About two to three droplets of the juice were inserted into a handheld digital refractometer (ATAGO, Tokyo, Japan). The samples were measured three times for replication and then the average value was taken. The results were expressed in % Brix unit.

Total reducing sugar. The reducing sugar analysis was carried out according to Somogyi (1937) as modified by Nelson (1944). One milliliter of the juice extracted for the total soluble solid analysis was added to a test tube that contained 25 mL Nelson A, 1 mL Nelson B, and 1 mL cupric reagent solution. The test tubes were heated in a water bath (Memmert, Schwabach, Germany) for 20 min and cooled. Afterward, 2 mL arsenic-molybdic reagent was added to the tube and mixed until homogeneous before adding 7 mL of distilled water. The samples' absorbance was read using a spectrophotometer (λ = 540 mm) (Thermo Fischer Scientific, Massachusetts, America). The results were reported as the percentage of reducing sugars (%).

Total titratable acid. The total titratable acid analysis was conducted according to Ranganna (1986). From a box of nine guava fruits, one was selected randomly to be measured. The chosen sample was mashed, and 10 g were taken to be added into a 100 mL volumetric flask. After that, distilled water was added until it reached the 100 mL mark. The solution was then mixed until homogeneous and filtered using filter paper. Then, 10 mL of the filtrate was transferred to an Erlenmeyer. Two to three drops of the indicator of 1% phenolphthalein were added. Titration was conducted using NaOH 0.1 N until the solution turned a pinkish color. The volume of NaOH 0.1 N used for the titration was recorded to be calculated and converted to the total titratable acidity value. The total titratable acidity (%TA) was calculated with the equation

$$\%TA = (V \times N \times MW \times df \times 100\%)/(m \times 1000 \times v)$$

where V = volume of NaOH 0.1 N used (mL), N = normality of NaOH used, MW = molecular weight of dominating acid (molecular weight of citric acid = 192), df = dilution factor, m = mass of sample (g), and v = valence of dominant acid (valence of citric acid = 3). The results were reported as percentages (%)

Organoleptic tests. In this study, the organoleptic test used a hedonic test where the perception of the sample's color, aroma, taste, texture, and overall acceptability was measured. The measurement used a ranking test with a 9-point scale (Meilgaard *et al*., 2006) where a score of 1 is the lowest score (dislike extremely) and 9 is the highest (like extremely). The hedonic test was done with 50 panelists (ratio male: female is 1:1) from academic staff and students of Universitas Muhammadiyah Yogyakarta. The panelists were aged between 18 and 60 years old.

Statistical analysis

The results of firmness, total soluble solids, total reduced, sugar and total titratable acid were analyzed with one-way ANOVA. Means were separated and analyzed using the Duncan multiple range test (DMRT, α = 5%) using Statistic Analytical Software (SAS) version 9.4.

3. Results and Discussions

Firmness

The firmness analysis of guava treated with alginate-based edible coating and different concentrations of CBLP is exhibited in Table 1. All samples show declining trends during the 20 days of observation. A sudden drop can be seen in samples coated with alginate but no addition of CBLP after four days of storage and the firmness continues to decrease. Compared to these samples, the samples treated with the addition of CBLP in alginate shows slower decrease of firmness. The different values between control and treated samples indicated that the edible coating could prevent firmness loss during storage.

In this study, samples coated with the addition of the lowest CBLP concentration shows the highest firmness after 20 days of storage. Similar result was also seen in the application of aloe vera and sage essential oil in tomatoes (Tzortzakis *et al*., 2019). After 7 days of storage, tomato with aloe vera and 0.1% sage essential oil had lower softening compared to the addition of 0.5% sage essential in aloe vera. Another study reported that apples coated with higher concentration of lemongrass oil and oregano oil showed sudden firmness drop (Rojas-Graü *et al*., 2007). A possible explanation of this result is the low pH of coating solution due to the higher concentration of essential oil was added.

This result occurred because the sample coated with alginate and CBLP had a more effective gas diffusion barrier than the control sample, therefore, enzymes that were involved in respiration and tissue softening will be less active. Firmness and juiciness of fruit is an important parameter that also relates to the marketability. The firmness of fruit is correlated to the pectin content on the cell walls. Due to pectin solubilization, the texture of fruits will be softer and resulted in firmness loss. This pectin solubilizations can be caused by several reasons, such as the depolymerization of pectin by pectinase enzymes (i.e., polygalacturonase, cellulase and pectin methyl esterase)

Table 1 - Result of firmness in kg/cm^2 of guava treated with alginate-based edible coating enriched with different concentration of *Cyclea barbata* leaves powder (CBLP)

Treatments	Observation days					
	0	4	8	12	16	20
Control	3.58 ± 0.13 a	0.60 ± 0.09 c	0.58 ± 0.02 d	0.28 ± 0.01 c	0.12 ± 0.01 c	0.08 ± 0.02 d
2% alginate + 0.2% CBLP	3.56 ± 0.07 a	2.81 ± 0.18 a	2.58 ± 0.13 ab	2.35 ± 0.23 a	1.99 ± 0.14 a	1.76 ± 0.05 a
2% alginate + 0.4% CBLP	3.05 ± 0.05 c	2.43 ± 0.05 b	2.34 ± 0.13 bc	2.29 ± 0.13 a	1.99 ± 0.17 a	1.58 ± 0.10 b
2% alginate + 0.6% CBLP	3.03 ± 0.22 b	2.83 ± 0.06 a	2.23 ± 0.15 c	1.97 ± 0.15 c	1.65 ± 0.14 b	1.39 ± 0.09 c
2% alginate + 0.8% CBLP	3.34 ± 0.27 ab	2.87 ± 0.11 a	2.72 ± 0.17 a	2.22 ± 0.08 b	1.95 ± 0.07 a	1.55 ± 0.03 b

Results followed by the same letter(s) imply that there is no significant difference between results according to the Duncan multiple range test (p>0.05).

and the loss of neutral chains (arabinan and galactan) which binds pectin to the cell wall via glycans or cellulose matrix (Paniagua *et al.*, 2014). By adding edible coating, the pectinase enzymes activity is lower and firmness loss is hindered (Zhou *et al*., 2010).

Another factor of the firmness is the transpiration of fruit. The balance between water loss and water uptake highly affected mechanical properties of the skin by controlling cell turgor. When turgor is removed by membrane matrix disassemble (i.e., solubilization of pectin during ripening), water can move freely which results in cell walls relaxation (Brüggenwirth and Knoche, 2016). Fruit transpiration is highly correlated with the water vapor pressure of airspace inside of the fruit and the air directly outside as the driving force (Montanaro *et al.*, 2012). Even after harvesting, detached fruit has sufficient water content to support an additional of 10 hours transpiration without moisture supply from xylem/phloem supply. The application of edible coating can generate a layer to delay transpiration (Kocira *et al*., 2021). Thus, a possible mechanism of alginate and CBLP as edible coating is by generating a water vapor barrier to lower water content loss of fruit.

Total soluble solids

Table 2 exhibits the results of total soluble solids with different CBLP concentrations. The result of total soluble solids indicates the total sugars in the sample. All samples had an increase at the beginning of storage time followed by a decline until the last observation day. This increase of total soluble solids during the ripening stage in guava was previously reported (Patel *et al*., 2014). It was also explained that the increase can be from depolymerization of polysaccharides and conversion of fruit starch to sugars.

However, all samples showed a decline in total dissolved solids after 20 days due to the senescence phase. A similar trend of total soluble solids was also reported in the application naphthalene acetic acid (NAA) and potassium nitrate as pre-harvest treatments on the storage quality of winter guava (Mandal *et al*., 2012). At the beginning of storage, hydrolysis of insoluble polysaccharides to simple sugars resulted in the increase of total soluble solids (Brothakar *et al*., 2002). Within time, all the insoluble polysaccharides will be completely hydrolyzed while soluble solids and organic acids will be used for respiration. This leads to the decrease of total soluble solid.

The fall of total soluble solids content in mature fruit towards senescence has also been reported in mango fruits. The same study investigated the effect of different concentrations of Bavistin DF solution to extend shelf-life as a postharvest treatment on mango fruits. The trend of total soluble solids observed in the control samples indicated that they underwent a faster maturation stage and headed towards senescence (Islam *et al*., 2013). On day 20, samples coated with 2% alginate and 0.8% CBLP had the lowest level of total dissolved solids. The higher the amount of CBLP, the lower the total dissolved solids were.

The mechanism of edible coating in inhibiting starch degradation which leads to the increase of total soluble solids during fruit ripening is by the decrease of respiration rate. The degradation of cell walls and starch to soluble sugars and organic acids act as a supply of carbons during climacteric respiration of fruit (Colombié *et al*., 2016). Guava is considered climacteric fruit, indicated by the inclined ethylene production at the peak of ripening (Ishartani *et al.,* 2018). The edible coating of alginate and CBLP in guava created an additionally layer that can hinder the respiration rate; thus, lowering the conversion rate of starch to total soluble solids.

Table 2 - Result of total soluble solids in % Brix unit of guava treated with alginate-based edible coating enriched with different concentration of *Cyclea barbata* leaves powder (CBLP)

Treatments	Observation days					
	0	4	8	12	16	20
Control	7.27 ± 0.06 a	7.30 ± 0.10 a	7.47 ± 0.15 a	7.88 ± 0.07 a	8.19 ± 0.03 a	7.03 ± 0.06 a
2% alginate + 0.2% CBLP	6.53 ± 0.07 b	6.90 ± 0.10 b	7.03 ± 0.06 b	7.13 ± 0.04 b	7.15 ± 0.05 c	6.73 ± 0.12 b
2% alginate + 0.4% CBLP	5.36 ± 0.14 c	6.20 ± 0.20 d	6.82 ± 0.04 c	7.10 ± 0.00 b	7.23 ± 0.00 b	6.71 ± 0.10 b
2% alginate + 0.6% CBLP	5.27 ± 0.06 c	7.00 ± 0.10 b	7.03 ± 0.00 b	7.15 ± 0.05 b	7.23 ± 0.06 b	6.39 ± 0.13 c
2% alginate + 0.8% CBLP	5.42 ± 0.25 c	6.62 ± 0.08 c	6.85 ± 0.12 c	7.07 ± 0.06 b	7.05 ± 0.02 d	6.17 ± 0.06 d

Results followed by the same letter(s) imply that there is no significant difference between results according to the Duncan multiple range test ($p>0.05$).

Total reducing sugar

The results of total reducing sugar analysis with different edible coating concentrations on guava fruits are shown in Table 3.

All samples show an increase in sugar reduction throughout the observation time. These results are similar to those of a previous study, where different varieties of guava were investigated for their total reducing sugars after 5 months of storage time at ambient temperature (Choudhary *et al*., 2008). The reducing sugars may be increased in the senescence phase of climacteric fruits due to starch hydrolysis to glucose, fructose, and sucrose (Patel *et al*., 2013). A high level of reducing sugars indicates rapid starch hydrolysis in fruit.

The reducing sugar content in guava is varied within different varieties (Choudhary *et al*., 2008). The highest level of reducing sugar is fructose, followed by glucose (Mowlah and Itoo, 1982). After the ripening stage, reducing sugar content of guava were found to be decreasing in overripe fruits (Bashir and Abu-Goukh, 2003). However, a clear explanation about this decrease has not been fully understood due to the complex process of starch breakdown, sugar synthesis and sugar metabolism in fruits are very complex which involves not only by ethylene but also an abundant of hormones and enzymes (Cordenunsi-Lysenko *et al*., 2019). In addition to this complexity, different fruits may possess different metabolic pathway of sugar. Previously, a study was conducted to investigate the sugar metabolism of peach during fruit development (Desnoues *et al*., 2014). The proposed pathway mentioned a conversion of fructose and glucose to fructose 1,6-bisphosphate (F16BP) which involved in the glycolysis and respiration flux.

On the last observation day, samples with 2% alginate and 0.8% CBLP showed the lowest reducing sugar level. This implies that the addition of 0.8% CBLP mixed with alginate could suppress starch hydrolysis into glucose, sucrose, and fructose. The edible coating with polysaccharide base and CBLP acted as a selectively permeable membrane towards CO_2 and O_2 gases' diffusion. This characteristic may extend shelf-life, as fruit's respiration rate became slower (Kocira *et al*., 2021). CBLP has an alcohol content that could inhibit fruit senescence when added in alginate (Viña *et al*., 2000).

Total titratable acid

The analysis of total titratable acid in guava fruits treated with different concentrations of the edible coating was conducted. The results are exhibited in Table 4.

Table 3 - Result of total reducing sugar in percentage (%) of guava treated with alginate-based edible coating enriched with different concentration of *Cyclea barbata* leaves powder (CBLP)

Treatments	Observation days					
	0	4	8	12	16	20
Control	9.33 ± 0.06 b	9.94 ± 0.02 b	12.16 ± 0.05 a	12.34 ± 0.00 b	13.59 ± 0.00 a	15.29± 0.02 a
2% alginate + 0.2% CBLP	9.76 ± 0.05 a	10.13 ± 0.02 a	10.14 ± 0.03 e	11.50 ± 0.06 c	12.21 ± 0.13 a	13.37 ± 0.00 d
2% alginate + 0.4% CBLP	8.98 ± 0.13 c	9.46 ± 0.03 d	10.30 ± 0.06 d	13.00 ± 0.04 a	13.45 ± 0.21 a	13.57 ± 0.02 b
2% alginate + 0.6% CBLP	8.69 ± 0.03 d	9.76 ± 0.07 c	11.38 ± 0.04 b	12.97 ± 0.05 a	13.03 ± 0.38 a	13.30 ± 0.03 e
2% alginate + 0.8% CBLP	8.24 ± 0.06 e	9.70 ± 0.07 c	10.55 ± 0.11 e	10.98 ± 0.06 d	12.03 ± 0.08 c	13.42 ± 0.04 c

Results followed by the same letter(s) imply that there is no significant difference between results according to the Duncan multiple range test (p>0.05).

Table 4 - Result of total titratable acid in percentage (%) of guava treated with alginate-based edible coating enriched with different concentration of *Cyclea barbata* leaves powder (CBLP)

Treatments	Observation days					
	0	4	8	12	16	20
Control	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	1.11 ± 0.003 a	1.78 ± 0.003 a	2.01 ± 0 a
2% alginate + 0.2% CBLP	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	0.81 ± 0.001 ab	1.13 ± 0.003 ab	1.56 ± 0 b
2% alginate + 0.4% CBLP	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	1.13 ± 0.003 ab	1.34 ± 0 c
2% alginate + 0.6% CBLP	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	1.13 ± 0.003 ab	1.34 ± 0c
2% alginate + 0.8% CBLP	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	0.67 ± 0 b	0.67± 0 b	0.67 ± 0 b

Results followed by the same letter(s) imply that there is no significant difference between results according to the Duncan multiple range test (p>0.05).

As a climacteric fruit, guava will have a sudden increase in respiration along with or before the senescence stage due to increases in CO_2 and ethylene after the climacteric phase (Tripathi *et al*., 2016). Therefore, the level of total titratable acid has frequently been used to indicate the shelf-life of fruit. According to the results, most of the samples had an increase in total titratable acid starting from day 12, except the samples coated with 2% alginate + 0.8% CBLP. This result is different from a previous study of guava (cv. Sardar), in which titratable acidity decreased after 40 days of storage (Mandal *et al.,* 2012). This reduction of total titratable acid level during storage was due to guava, as climacteric fruit, during the peak of ripening resulted in the rise of malic enzyme activity and pyruvate decarboxylation. Therefore, respiration rate and metabolic activity such as degradation of organic acids.

However, similar to the results in this study an increase of total titratable acidity level in guava fruits was also observed (Dube *et al*., 2015). In their study, the total titratable acidity increased until 120 days of storage, after which it declined. The increase of total titratable acidity is correlated to the undissociated organic acids level in the maturation of fruit which is stored in the vacuole of cell plants. When ripening stage begin, organic acids will be depleted as substrates in respiration. Therefore, this indicate that the samples were not fully ripen during harvesting.

Total titratable acid in guava coated with alginate and CBLP tended to have a lower rate of increase. This indicates that the edible coating with alginate and CBLP could decrease the respiration rate and suppress the use of organic acid, followed by maintaining the amount of total acid in guava throughout the storage time. According to Paul and Pandey (2014), fruit's deterioration rate is affected by O_2 and CO_2 gases' diffusion through the lenticel on the fruit's surface (Paul and Pandey, 2014). The O_2 gas entering the sample will increase the respiration rate, causing further deterioration. The sturdy edible coating of 2% alginate + 0.8% CBLP on the fruit's surface prevented gas diffusion, which resulted in no significant increase of total titratable acidity.

Organoleptic tests

The visual appearance of samples before and after 20 days of storage can be seen in figure 1. From the appearance after 20 days, samples with no edible coating applied showed yellowish color and went into deterioration stage. In contrast, samples with edible coating were visibly similar in appearance with light green color.

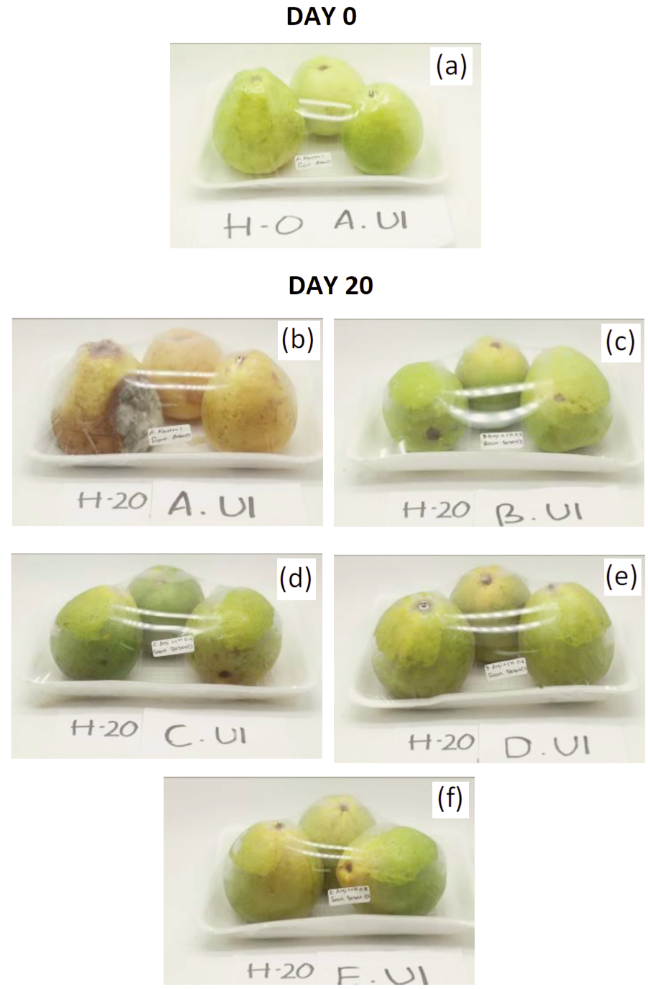

Fig. 1 - Visual appearance of guava fruit on day 0 (a) and after 20 days of storage with: no edible coating (b); 0.2% alginate + 0.2% Cyclea barabata leaves powder (CBLP) (c); 0.2% alginate + 0.4% CBLP (d); 0.2% alginate + 0.6% CBLP (e); 0.2% alginate + 0.8% CBLP (f).

For organoleptic testing, a hedonic test was conducted to evaluate the sensory qualities of guava fruits treated with different edible coating concentrations. The results of the analysis are shown in figure 2. Based on the organoleptic test, samples coated with 2% alginate + 0.8% CBLP had the best score in the color, taste, and texture parameters. This is because a higher CBLP concentration in the edible coating would further inhibit the respiration and transpiration rates. The best score for the aroma parameter was obtained by an edible coating with 0.2% CBLP. This is because the alcohol level due to fermentation in CBLP gave an unpleasant odor; thus, the lowest concentration gave the best score of

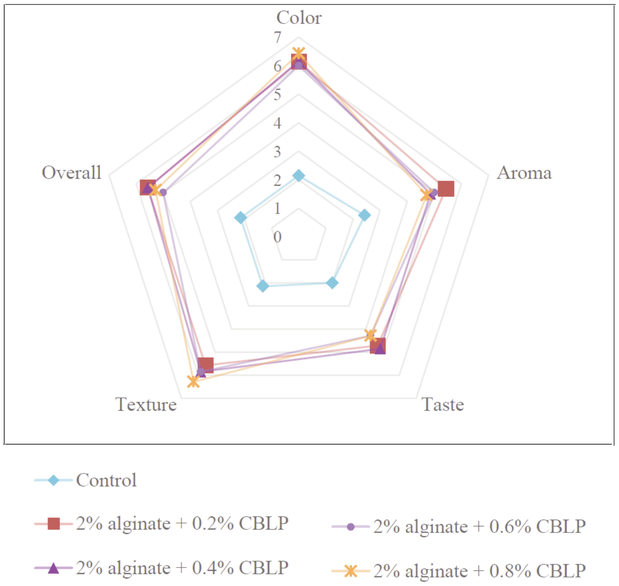

Fig. 2 - Result of organoleptic tests of guava treated with alginate-based edible coating enriched with different concentration of *Cyclea barabata* leaves powder (CBLP).

aroma quality. The highest overall score was obtained by two different concentrations of CBLP: 0.2% and 0.4%.

Moreover, edible coating with 0.4% CBLP had the highest score of taste.

In general, samples coated with alginate and CBLP had a higher score for sensory analysis compared to control samples. Similar results were obtained from fresh-cut mango coated with polysaccharide-based edible coatings: samples coated with alginate had the highest consumer acceptance due to their ability to prevent firmness loss (Salinas-Roca *et al.*, 2018). The maintenance of sensory quality by alginate-based edible coating on fruits were also found on strawberry, water apples and apple fresh-cut (Guerreiro *et al.*, 2015; Utama *et al.*, 2020; Marghmaleki *et al.*, 2020).

4. Conclusions

Different concentrations of CBLP in an alginate-based edible coating to extend the shelf-life of guava fruit were evaluated. The samples treated with 2% alginate and 0.8% CBLP had the significantly lowest level of total dissolved solids, total reducing sugar, and total titratable acidity and the highest scores on color, taste, and texture parameters in the organoleptic tests. From the analysis of firmness and organoleptic tests, the lowest firmness loss and highest score for aroma parameters were observed in samples treated with 2% alginate and 0.2% CBLP. Therefore, these results imply that the application of an edible coating based on alginate with the addition of CBLP can maintain the physicochemical and sensory properties of guava fruits.

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