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Effectiveness of sugar palm fruit (*Arenga pinnata* (*Wurmb*) *Merr*.) and chitosan as edible coating on cherry tomatoes (*Solanum lycopersicum* var. *cerasiforme*)

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Abstract

Cherry tomatoes are a highly consumed yet highly perishable fruit. One of the post-harvest treatments to extend the shelf-life of the fruits is edible coating technology. This study was conducted to evaluate and compare the effectiveness of commercial liquid chitosan and sugar palm fruit as an edible coating in delaying the ripening of cherry tomatoes. Edible coatings were applied to cherry tomatoes using the dipping method. The analyses consisted of weight loss, pH and colour changes during an 18-day storage. The rates of the quality changes were calculated to compare the effectiveness of both edible coatings. The results showed that edible coating from chitosan and sugar palm fruit slurry (sugar palm fruit-water with the ratio of 1:6 added with 1% glycerol (b/v)) could significantly retard weight loss and changes in pH, L*, a*, b* and ΔE* values of cherry tomatoes stored at room temperature. Analysis of variance for the rates of changes of all measured parameters showed no significant difference ($p>0.05$) between commercial liquid chitosan and sugar palm fruit as an edible coating. These results inferred that both coating materials had similar effectiveness in delaying the ripening process of cherry tomatoes stored at room temperature.

1. Introduction

Cherry tomatoes are one of the most widely sought tomatoes due to their practicality for consumption. Cherry tomatoes are higher in sugar (3.6 g/100 g) than regular tomatoes (3.0 g/100 g) and hence taste sweeter. They are rich in nutrients and antioxidants such as lycopene, β-carotene, flavonoids, vitamin C and others (Menezes *et al*., 2012; Abdel-Razz *et al*., 2013). Although cherry tomatoes have high economic value, their shelf life is relatively short. Red cherry tomatoes can only last for 7-8 days (Rudito, 2012).

The high perishability of cherry tomatoes is due to their climacteric characteristics. Biochemical changes during storage such as increased respiration rate and ethylene production result in the rapid quality decrease and spoilage of cherry tomatoes. Hence, proper postharvest treatments should be applied to maintain the quality and prolong their shelf life. Many research on post-harvest handling of fruits and vegetables have been done, among them focusing on the use of edible coating. Edible coating is a layer coated on the surface of fruits to slow down their ripening and senescence process during storage and consequently prolong the shelf life. The edible coating should be safe and easy to apply. Hydrocolloids are one of the ingredients for edible coating (Dhall, 2016), among them are hydrocolloids from chitosan and, to a lesser extent, sugar palm fruit (*Arenga pinnata* (*Wurmb*) *Merr*.). The use of them as edible coating will subsequently increase the valorization of the two commodities.

Chitosan is a biopolymer resulting from the deacetylation of chitin as a byproduct from shrimp and crab processing as well as from mushrooms. Physiologically, chitosan can form a film on the surface of fruits and vegetables that reduces their respiration rate by adjusting the permeability against carbon dioxide and oxygen, hence slowing down metabolism and lengthening the shelf life of the fruits and vegetables (Aider, 2010; Elsabee and Abdou, 2013). Chitosan also displays antimicrobial activity against some molds and bacteria commonly found in foods (Assis and de Britto, 2011). Chitosan is generally prepared by dissolving its powder form in acetic acid prior to application.

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Nowadays, liquid chitosan is also available commercially.

Sugar palm fruits, known as *kolang-kaling* in Indonesia, are the processed product of the endosperm part of the young to mid-ripe *Arenga pinnata* (*Wurmb*) *Merr*. fruits. It has a chewy texture and is white in colour. Sugar palm fruits contain galactomannan which can form a highly viscous solution at low concentrations, making it suitable for edible coating. Galactomannan is a polysaccharide consisting of a mannose backbone with galactose side groups (Cerqueira *et al*., 2011). The benefit of using sugar palm fruit as an edible coating is that the fruits are widely available in many tropical countries at relatively cheap prices (Santoso, 2010).

Chitosan and sugar palm fruits are potential ingredients to be used as edible coating for cherry tomatoes. A study on the application of commercial liquid chitosan and sugar palm fruits as edible coating to prolong the shelf life of cherry tomatoes at room temperature storage is not available yet. This study aimed to compare the effectiveness of commercial liquid chitosan and sugar palm fruits as edible coating to retard the ripening process of cherry tomatoes.

2. Materials and methods

2.1 Location and time

This study was carried out at the Food Processing and Food Biochemistry Laboratory, Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, IPB University. The study was conducted for 5 months (February – June 2020).

2.2 Materials and equipment

Cherry tomatoes used in this study were obtained from PT Nudira Fresh, Pengalengan, Bandung at the ripening stage of light red (light red colour on 60 – 90% of the fruit). Liquid chitosan was from PT Berkah Inovasi Kreatif Indonesia, Babakan, Bogor and sugar palm fruits with a clear white colour and chewy texture were bought at Simpang Tiga Market, East Jakarta. Other materials included potable water, distilled water and PET fruit packaging (14 cm × 10 cm × 6 cm).

The equipment used were basin, pan, plates, glasses, beaker glass of 100 mL, thermometer, knives, filter cloth, blender, fan, timer, analytical and digital balance and stoves. For colour measurement, a camera (Xiaomi Redmi Note 5 smartphone, 12 megapixel and lens f/1.9), pH meter (ATC), mini photo studio of 30 cm × 40 cm × 30 cm with 6000 K LED lamp and computer were used.

2.3 Sample preparation

2.3.1 Formulation of water and sugar palm fruit ratio

Sugar palm fruit slurry was used as an edible coating. The slurry was prepared by mixing sugar palm fruits with water using a blender. The ratio of the fruit and water was 1:4, 1:6 and 1:8. These three different formulations of sugar palm fruit edible coating (SPF) were used to coat cherry tomatoes. Cherry tomatoes were dipped into the edible coating slurry for 5 mins and were exposed to a fan to dry for 1 hr at room temperature. The uncoated samples were used as control. All samples were packaged in PET plastic and stored at room temperature. Colour changes were observed visually for 3 days. The sugar palm fruit edible coating formula that could best retard colour changes on the cherry tomatoes was selected for the next step of the study.

2.3.2 Addition of plasticizer on sugar palm fruit edible coating

This step was done to evaluate the effect of plasticizer on the ability of the previously selected edible coating formula to delay the ripening process of cherry tomatoes. The addition of plasticizer was based on Santoso (2010) who added 1% glycerol (b/v) into the edible coating. The selected sugar palm fruit edible coating formula without (SPF) and with the addition of 1% glycerol (b/v) (SPFG) was applied to cherry tomatoes. The weight loss and colour changes of the cherry tomatoes were then observed for 3 days. The best edible coating formula for inhibiting the weight loss and colour changes of cherry tomatoes was selected for the next step of the study.

2.3.3 Application of liquid chitosan and sugar palm fruit edible coating on cherry tomatoes

This step aimed to observe and compare the effect of the application of liquid chitosan and sugar palm fruit edible coating (SPFG) selected in the previous step on the quality changes of cherry tomatoes during 18-day storage. Cherry tomatoes were harvested one day prior to treatment or storage. The application of edible coating was done based on Tzortzakis *et al.* (2019) with modification. Cherry tomatoes were dipped into either edible coating suspension (SPFG or liquid chitosan) for 5 mins followed by drying with a fan for 1 hr at room temperature. The uncoated samples were used as a control. All samples were packaged in PET plastic and stored at room temperature. The observation was done every 3 days. The experiment was done with 2 replications. The effectiveness of both edible coatings was compared based on the rate of quality changes

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(weight loss, pH changes and colour changes) during storage.

2.4 Sample analysis

2.4.1 Weight loss percentage

Changes in the weight of cherry tomatoes were measured using an analytical balance. Weight loss was determined from the difference of the sample weight before and after i-day of storage and was calculated as percentages on the fresh weight basis, where i was the observation day/ storage interval.

$$\text{Weight loss}(\%) = [(\text{initial weight} - \text{weight on day}_i)/\text{initial weight}] \times 100\%$$

2.4.2 Degree of acidity (pH)

The pH of cherry tomatoes was measured using an ATC pH-meter according to the method by AOAC (2012). The instrument was standardized prior to usage with a buffered solution of pH 4.0 and 7.0. Samples were crushed using a blender or mortar. The electrode was dipped into the sample and let sit until a stable measurement value was obtained. The pH measurement was done in duplicate.

2.4.3 Colour measurement

Colour measurement of the cherry tomatoes was done using a smartphone camera according to Mella (2016) with modification. The sample was placed in a mini studio of 30 cm × 40 cm × 30 cm with an LED lamp as the source of light with a colour temperature of 6000 K. The sample was placed in the middle part of the mini studio right under the hole for taking pictures. The lamp was placed on the upper part of the mini studio, resulting in 30^{o} angle against the sample. Pictures were taken using a smartphone camera (12 megapixels, ISO Auto, with no blitz) from the hole above the sample.

The colour characteristics of the samples were assessed using Adobe Photoshop CS6 software to measure the L, a* and b* values. The photos taken in the mini studio were uploaded to the software. The colour unit was then converted from RGB to CIELab. Three measurements were taken for each sample. Using colour sampler feature from tools layout, 3 spots from the sample photo were picked randomly. The area of colour sampling was set to 5 × 5 pixel. The L*, a*, and b* values for each spot were displayed on the *info* window next to the photo.

The ΔE* value was used to determine the overall colour changes of the cherry tomatoes during storage. ΔE* value was calculated as follows:

$$\Delta L^* = L^*_0 - L^*_i$$

$$\Delta a^* = a^*_0 - a^*_i$$

$$\Delta b^* = b^*_0 - b^*_i$$

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where: 0 = day-0 and i = day-3, -6, -9, -12, -15, -18

2.5 Statistical analysis

Data were subjected to analysis of variance (ANOVA). Significant differences between means were determined by Duncan post hoc test at a 5% significance level. Data of weight loss and pH were expressed as mean ± SD.

3. Results and discussion

3.1 Ratio determination of sugar palm fruit and water

This step was done to determine the best sugar palm fruit and water ratio for edible coating (hereafter referred to as SPF). It was reported that the higher the concentration of edible coating slurry, the thicker the coating layer of the fruits, resulting in better inhibition of gas and moisture transmission (Mudyantini *et al*., 2018). On the other hand, Dhall (2016) mentioned that an excessively thick coating layer might lead to anaerobic respiration due to low oxygen concentration in the fruits. The appropriate concentration of edible coating slurry will limit gas transmission and reduce the rate of respiration properly. This condition would in turn slow down the metabolism rate of the commodities and delay the ripening process (Volpe *et al*., 2019).

In general, coated cherry tomatoes displayed slower colour changes compared to control (Figure 1). Exception was for samples with SPF 1:8 which showed the same yellowish-red colour as the control on day-3 of storage. This indicated that the SPF 1:8 was not effective in delaying colour changes in cherry tomatoes.

After being stored for 3 days, the SPF 1:4 was able to maintain 1 cherry tomato greenish-yellow with a tint of red and 3 tomatoes reddish-yellow. The SPF 1:6 maintained 1 tomato greenish-yellow with a tint of red, 2 tomatoes reddish-yellow and 1 tomato yellowish-red. These two formulas gave similar results on tomatoes. This was inconsistent with a previous study that suggested that higher edible coating concentration posed better inhibition toward the ripening process of fruits (Mudyantini *et al*., 2018). It was presumed that this difference was because the coating layer was very brittle and easily cracked. The brittleness increased with a higher concentration of sugar palm fruits. The inconsistent coverage and cracks might cause the whole tomato's surface to not be fully covered by the edible coating, compromising the inhibition of transpiration and respiration rate.

From the experiment, the ability to retain colour changes of cherry tomatoes between the SPF 1:4 and

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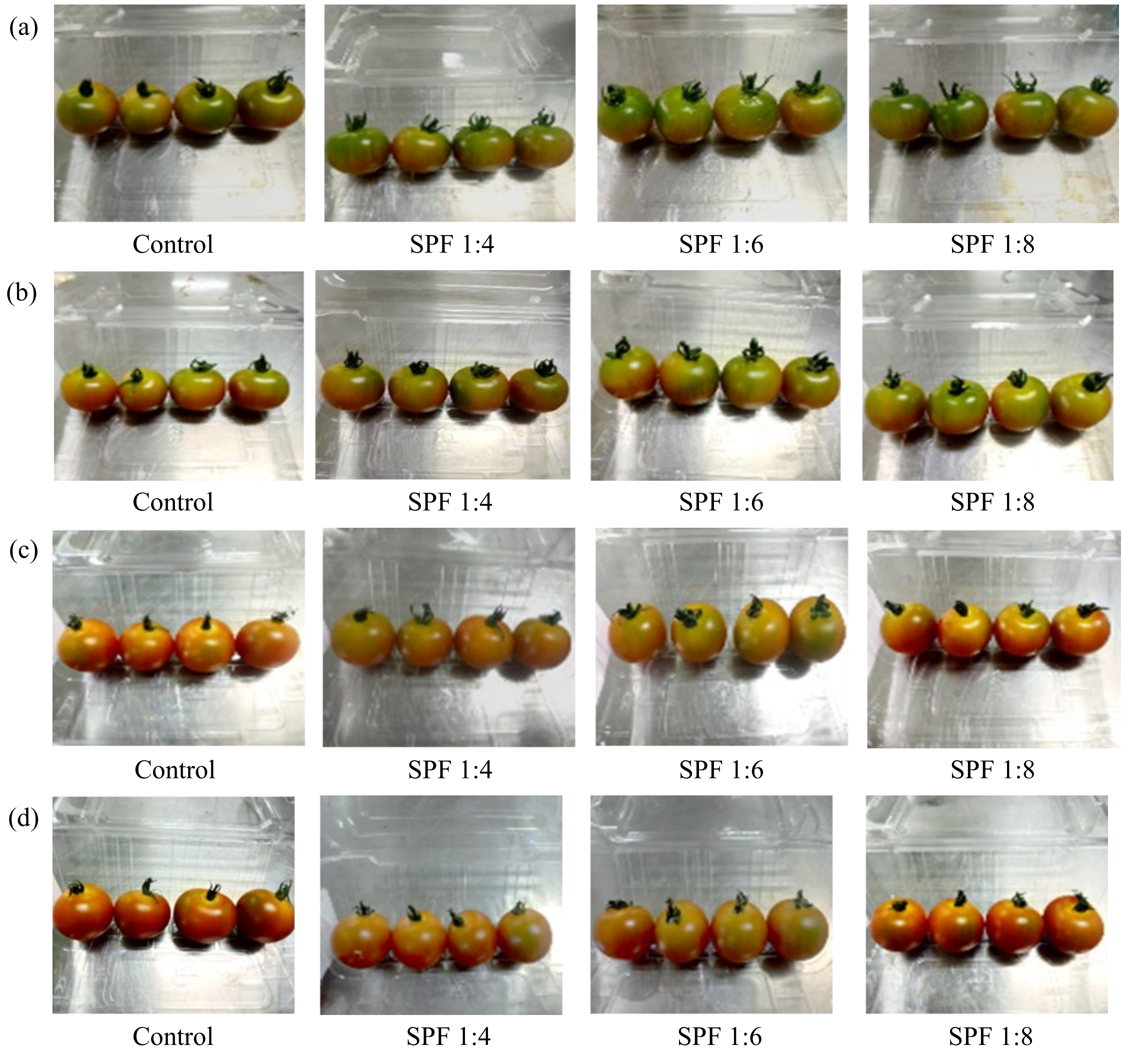

Figure 1. Color changes of cherry tomatoes with sugar palm fruit edible coating (SPF) treatment on day- (a) 0, (b) 1, (c) 2 and (d) 3 of storage at room temperature

SPF 1:6 was deemed similar. The SPF 1:6 produced a higher volume of edible coating than the SPF 1:4 with the same amount of sugar palm fruits. Therefore, the 1:6 sugar palm fruits-water formula was selected for further experiments based on effectiveness and economic considerations.

3.2 Effect of addition of plasticizer into sugar palm fruit edible coating on quality parameters of cherry tomatoes

The previous step demonstrated that sugar palm fruit slurry as edible coating managed to slow down colour changes on cherry tomatoes. However, the layer was very stiff, brittle and easily cracked. It was presumed that this was due to the strong intermolecular force in the edible coating. The brittleness made it difficult for it to be used as an effective edible coating (Sothornvit and Krochta, 2005). The addition of plasticizer into the formula was expected to increase its flexibility and help with the brittleness (Dhall, 2016).

Winarti (2013) reported that glycerol is among plasticizers that are commonly used for its effectiveness and low price. Additionally, glycerol has smaller molecules than other commonly used plasticizers, such as sorbitol and polyethylene glycol. The smaller molecular size helps it incorporate better in the polymer network of the edible coating, resulting in better flexibility of the layer compared to when using other types of plasticizers (Ballesteros-Mártinez *et al*., 2020).

Figure 2 shows that coated cherry tomatoes experienced slower colour changes compared to the control. Sugar palm fruit edible coating added with 1% glycerol (b/v) (hereafter referred to as SPFG) displayed better inhibition to colour changes during 3 days of storage compared to the one without glycerol (SPF). On day 3 of storage, SPFG 1:6 edible coating managed to maintain 1 cherry tomato light green with a tint of red while the remaining 3 tomatoes were greenish-yellow with a tint of red. None of the tomatoes with SPF 1:6 edible coating maintained a light green colour. The latter treatment resulted in 1 tomato of greenish-yellow with a tint of red, 2 tomatoes of reddish-yellow, and 1 tomato of yellowish-red colour.

Figure 3 shows the effect of SPFG 1:6 and SPF 1:6 on the weight loss of cherry tomatoes. The weight loss of the cherry tomatoes increased with storage time. Cherry tomatoes belong to climacteric fruits, meaning that they

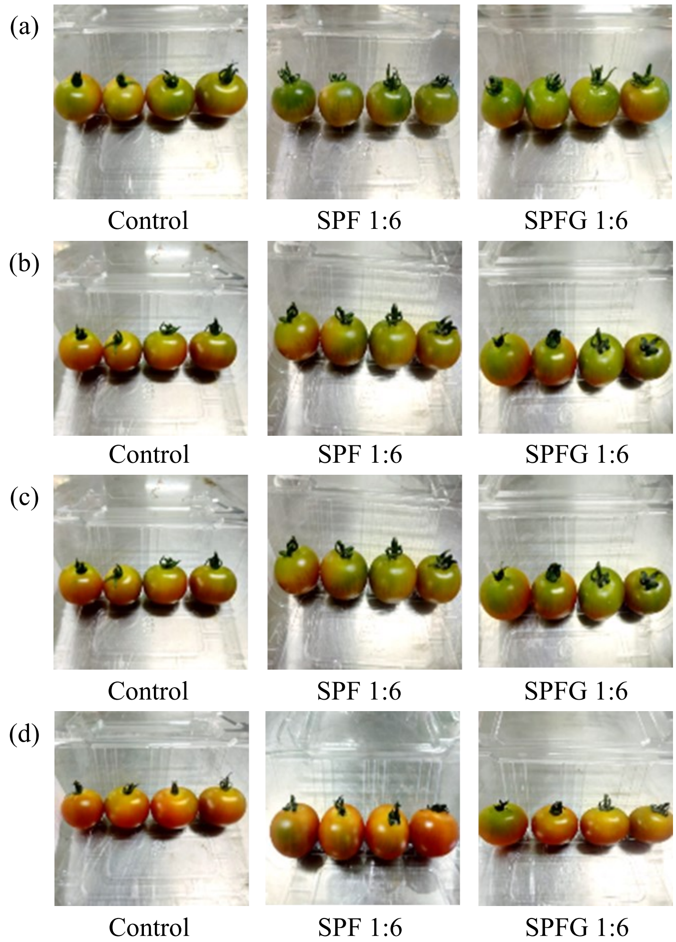

Figure 2. Effect of edible coating of SPF 1:6 (sugar palm fruit-water with ratio of 1:6), SPFG 1:6 (sugar palm fruit-water with ratio of 1:6 added with 1% glycerol (b/v)) on color changes of cherry tomatoes stored at room temperature on day - (a) 0, (b) 1, (c) 2 and (d) 3.

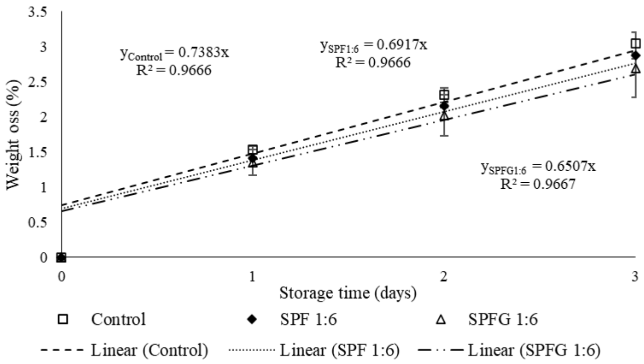

Figure 3. Effect of edible coating of SPF 1:6 (sugar palm fruit-water with ratio of 1:6), SPFG 1:6 (sugar palm fruit-water with ratio of 1:6 added with 1% glycerol (b/v)) on the weight loss of cherry tomatoes during 3-day storage at room temperature.

still undergo respiration and transpiration after being harvested. The rate of respiration and transpiration increases as the fruits ripen. This in turn would result in weight loss of the commodity.

On day 3 of storage, cherry tomatoes treated with SPFG 1:6 experienced the least weight loss compared to those with SPF 1:6 and control. The slope of linear regression displayed by SPFG 1:6 samples was smaller than that of other samples (Figure 2), indicating that the weight loss in this sample occurred more slowly each day relative to other samples.

The addition of 1% glycerol (b/v) to sugar palm fruit edible coating was expected to help it better cover the surface of the cherry tomatoes, indicated by the delayed colour changes and weight loss. As a plasticizer, glycerol reduces the intermolecular force of the polymer chain, hence increasing the flexibility of the formed film and reducing brittleness (Vieira *et al*., 2011). Based on these preliminary experiments, edible coating from sugar palm fruit with the addition of 1% glycerol (b/v) was used for the remaining experiments of the present study.

3.3 Quality changes of cherry tomatoes with chitosan and sugar palm fruit-glycerol edible coating

The effectiveness of the edible coating was compared between commercial liquid chitosan and SPFG in delaying the ripening process of cherry tomatoes. The parameters being observed included weight loss, pH changes and colour changes of the cherry tomatoes over the course of storage time.

3.3.1 Weight loss percentage

As seen in Figure 4, the weight loss of all samples increased during 18-day storage. The control/uncoated sample could only be stored until day 9, as the signs of spoilage had appeared. The control sample displayed the biggest weight loss compared to the coated ones. On day 9, the weight loss of uncoated samples, samples with chitosan edible coating, and samples with SPFG 1:6 were 12.79±1.34%, 7.84±0.42% and 7.91±0.04%, respectively. These results were in agreement with previous studies on edible coating using chitosan on mangoes (Eshetu *et al*., 2019), the combination of chitosan, pectin, and pullulan with antimicrobial agents

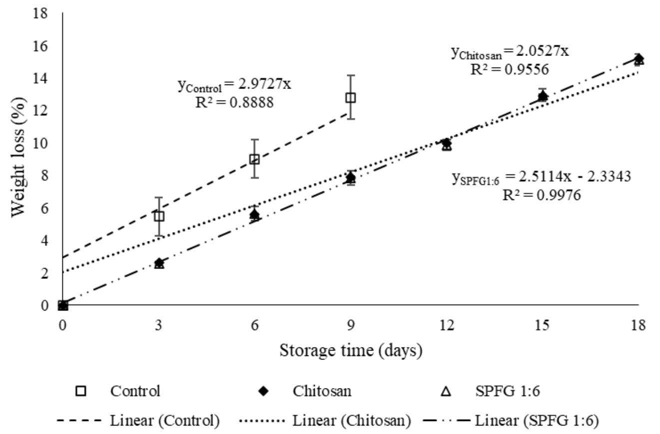

Figure 4. Weight loss (%) of cherry tomatoes during 18-day storage at room temperature with different edible coating treatments: control, chitosan, and SPFG 1:6 (sugar palm fruit-water with ratio of 1:6 added with 1% glycerol (b/v).

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on strawberries (Treviño-Garza *et al*., 2015) and guar gum on Roma tomatoes (Ruelas-Chacon *et al*., 2017).

As climacteric fruit, cherry tomatoes are biologically active and carry out respiration, transpiration and ripening during post-harvest time. It was known that the weight loss of fruits is due to the transfer of humidity and some oxidation and respiratory processes that naturally occur during storage. Increased transpiration rate would result in increased weight loss of the fruits due to moisture loss (Treviño-Garza *et al*., 2015). As the moisture evaporates, the skin wrinkles and the fruits shrink causing quality deterioration. It was suggested that polymeric edible coatings form a barrier layer against water vapor transmission hence inhibiting weight loss (Treviño-Garza *et al*., 2015; Ruelas-Chacon *et al*., 2017; Eshetu *et al*., 2019). In addition to water vapor, O_2 and CO_2 transmission are also inhibited by the presence of edible coating. This will in turn modify the internal atmosphere and slow down the respiration rate of fruit, hence reducing weight loss (Atress *et al*., 2010).

The slope of linear regression indicated the rate of weight loss per day during storage. The weight loss rate of the control sample (2.9727%/day) was significantly higher ($p < 0.05$) than that of the ones coated with chitosan (2.0527%/day) and SPFG (2.0446%/day). However, the weight loss rate between the samples with both edible coatings was not significantly different ($p > 0.05$). This result inferred that SPFG was as effective as chitosan as an edible coating in retarding the weight loss of cherry tomatoes during storage.

3.3.2 Degree of acidity (pH)

Changes in the pH of fruit are one of the indicators of the ripening process. During ripening, organic acids are used as substrates for respiration (Nandane and Jain, 2011). Hence, the pH of cherry tomatoes is expected to increase over time.

As seen in Figure 5, all samples of cherry tomatoes displayed increased pH during 18-day storage. This result was in agreement with the report by Tigist *et al*. (2013) who studied changes in cherry tomatoes during storage at ambient temperature. The initial pH of the control, sample coated with chitosan, and SPFG 1:6 was 4.15±0.01, 4.14±0.01 and 4.15±0.01, respectively. The pH of all samples was not different statistically ($p > 0.05$) indicating that chitosan and SPFG edible coating did not affect the pH of the fruits.

The control sample could only be stored for 9 days with a final pH of 4.57±0.01. On the same day, samples coated with chitosan and SPFG 1:6 had lower pH, 4.46±0.01 and 4.41±0.02 respectively. A lower pH value corresponds to a lower respiration rate (Tigist *et al*., 2013). Therefore, it could be inferred that both edible coating treatments were able to retard the respiration rate of cherry tomatoes, indicated by slower pH increases. This finding was in agreement with a previous study on mangoes using chitosan as an edible coating (Eshetu *et al*., 2019).

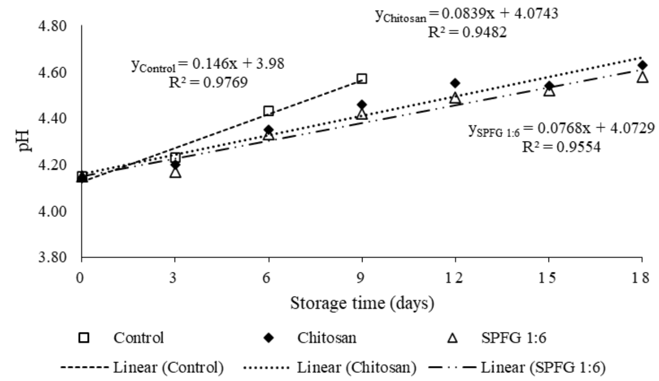

Figure 5. pH changes of cherry tomatoes during 18-day storage at room temperature with different edible coating treatments: control, chitosan, and SPFG 1:6 (sugar palm fruit-water with ratio of 1:6 added with 1% glycerol (b/v).

The slope of linear regression in Figure 5 indicated the rate of pH changes of the cherry tomatoes during storage. The pH changes for control, sample coated with chitosan, and SPFG 1:6 were 0.1460, 0.0839 and 0.0768 pH unit/day, respectively. Statistical analysis showed that the rate of pH changes was significantly different between samples with both edible coatings and control ($p < 0.05$), but not between chitosan and SPFG 1:6 treatment ($p > 0.05$). This suggested that both edible coatings displayed similar effectiveness in inhibiting pH changes in cherry tomatoes during storage. The effect was attributed to the ability of an edible coating to modify the internal atmosphere of the commodity and slow down respiration and other metabolism rates (Volpe *et al*., 2019).

3.3.3 Colour

The colour of cherry tomatoes is an important attribute of consumer acceptance. Cherry tomatoes underwent colour changes due to post-harvest respiration and transpiration processes. The rate of colour changes for coated and non-coated samples was compared through differences in their L*, a*, b* and ΔE values throughout storage time. The L*, a*, and b* values were determined according to the method by Mella (2016) with modification.

3.3.3.1 L values*

L* value is an approximate measurement of brightness/ luminosity and the values range between 0 (black) – and 100 (white) (Pathare *et al*., 2013). Table 1 shows that the L* values of cherry tomatoes with all

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Table 1. Changes in L*, a*, b*, ΔE values of cherry tomatoes with different edible coating treatments: control, chitosan, and SPFG 1:6 (sugar palm fruit-water with ratio of 1:6 added with 1% glycerol (b/v) during storage at room temperature.

Color Parameter	Storage time (days)	Control	Chitosan	SPFG 1:6
L*	0	53.00±1.18	52.92±0.12	52.58±0.12
	3	52.58±0.59	52.50±0.94	52.08±2.00
	6	46.50±1.89	53.25±1.06	53.08±0.82
	9	47.00±1.41	51.16±0.94	50.25±0.12
	12		50.33±0.71	50.75±1.30
	15		46.08±0.82	45.75±1.06
	18		45.08±2.24	44.42±0.59
Rate of changes (unit/day)		-2.4085[a]	-1.4133[b]	-1.4014[b]
a*	0	30.50±0.71	30.16±0.94	30.25±1.30
	3	42.42±1.53	36.92±0.59	37.84±0.47
	6	44.33±1.41	38.92±1.77	40.25±0.12
	9	46.16±0.94	40.17±0.71	40.50±0.47
	12		44.58±0.82	43.16±0.47
	15		45.00±2.12	43.34±0.47
	18		46.50±1.65	45.84±0.24
Rate of changes (unit/day)		4.8925[a]	2.5300[b]	2.1668[b]
b*	0	43.25±0.12	43.16±0.94	43.08±0.59
	3	40.75±1.06	41.16±0.94	41.83±0.71
	6	42.92±1.53	41.58±0.35	41.00±1.65
	9	41.16±0.24	41.08±0.12	41.50±0.00
	12		39.84±0.94	40.50±0.71
	15		41.34±1.65	41.08±0.35
	18		42.00±0.71	41.84±0.94
Rate of changes (unit/day)		-0.4075[a]	-0.1750[a]	-0.2054[a]
ΔE*	0	0.00±0.00	0.00±0.00	0.00±0.00
	3	13.78±2.28	11.02±1.04	12.42±1.08
	6	16.54±0.65	13.12±0.66	12.96±2.11
	9	17.68±1.33	12.02±1.21	12.26±1.39
	12		16.28±1.34	14.86±0.19
	15		17.87±0.72	16.59±0.37
	18		19.87±1.68	18.81±1.61
Rate of changes (unit/day)		4.9290[a]	3.1227[b]	2.2987[b]

Values are presented as mean±SD. Values with different superscripts are statistically significantly different by Duncan's test at $p < 0.05$.

treatments decreased over time. Observation on the control sample stopped at day 9 as they displayed signs of spoilage the day after.

Cherry tomatoes with edible coating showed higher brightness than control on each day of observation, except for day 0. Analysis of variance with Duncan's post hoc test showed that the L* values of cherry tomatoes with both edible coating treatments were not significantly different from that of the control on day 0 ($p > 0.05$). This inferred that coating with liquid chitosan and SPFG 1:6 did not affect the initial L* value of the cherry tomatoes.

Linear regression of the L* values for all samples was performed (data not shown). The slope of the linear regression indicates the reduction rate of L* value per day. The L* values of the control sample were reduced by -2.4085 unit/day while those of the samples coated with chitosan and SPFG 1:6 were reduced by -1.4113 and -1.4014 unit/day, respectively (Table 1). The reduction rates of the two coated samples were statistically lowered from that of the control ($p < 0.05$), but not significantly different from each other ($p > 0.05$). These results suggested that both edible coatings demonstrated similar effectiveness in retarding the reduction of brightness/luminosity of cherry tomatoes during 18 days of storage.

3.3.3.2 a values*

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a* values refer to reflection light resulting in chromatic of mixed red and green, with positive values for the reddish colour and negative values for the greenish one (Pathare *et al*., 2013). The a* values of all samples increased over time (Table 1). Increased a* values indicated that the tomatoes were turning redder and redder during storage, which was in agreement with the study by Tzortzakis *et al.* (2019).

From the results, it was evident that the a* values of the coated cherry tomatoes were always lower than those of the control during any interval of storage time. Similar results were reported by a previous study using Roma tomatoes (Ruelas-Chacon *et al*., 2017). The edible coating treatment did not affect the initial a* values of cherry tomatoes as the values were the same for all samples ($p > 0.05$).

Linear regression of the a* values for all samples was performed (data not shown). The slope of the linear regression indicates the rate of changes of the a* value per day. The a* values increased by 4.8925, 2.1668 and 2.5300 unit/day for sample uncoated samples and samples coated with chitosan and SPFG 1:6, respectively (Table 1). Statistical analysis showed that the rate of changes of the a* values of coated samples were significantly lower than those of control, but were not different from each other. This result demonstrated how liquid chitosan and SPFG 1:6 coating gave similar effectiveness in inhibiting a* value increase in cherry tomatoes during 18-day storage. It was reported that edible coating creates a modified atmosphere in the fruits the respiration rate which was responsible for the reddening of the fruits becomes inhibited (Ruelas-Chacon *et al*., 2017).

3.3.3.3 b values*

b* values referred to the chromatic colour of mixed blue-yellow, yellow for positive values and blue for negative values (Pathare *et al*., 2013). The b* values of all samples were relatively constant throughout storage time (Table 1). The linear regression of the b* value measurement for all samples showed a determination coefficient close to 0 (data not shown). This suggested that storage time hardly affected the b* value of the samples. Khairi *et al*. (2015) also reported that the b* values of tomatoes insignificantly changed during ripening and reached their peak at their pink-light red stage. Similar to L and a* values, chitosan and SPFG 1:6 coating also had no effect on the b* values of cherry tomatoes.

3.3.3.4 ΔE values*

ΔE* values can be used to determine the overall colour changes of cherry tomatoes during storage. Table 1 shows how ΔE* values increased for all treatments over time. It was evident that the ΔE* values of cherry tomatoes coated with chitosan and SPFG 1:6 were always lower than those of the control. This suggested that the colour of the samples changed slowly with edible coating treatments. A similar finding was reported by previous studies using various polymeric edible coating on different types of fruits, for example, chitosan on cherry tomatoes (Santos and Rahmat, 2013; Treviño-Garza *et al*., 2015; Abebe *et al*., 2017; Ruelas-Chacon *et al*., 2017; Volpe *et al*., 2019). The observation of the control samples in this study had to stop at day 9 as they started to show signs of spoilage the day after.

Linear regression of the ΔE* values for all samples was performed (data not shown). The slope of the linear regression indicates the rate of changes of the ΔE* value per day. The rate of ΔE* changes per day were 4.929, 3.1227 and 2.9874 unit/day for control and samples coated with chitosan and SPFG 1:6, respectively. Statistical analysis showed that the rate of changes of the ΔE* values of both coated samples was significantly lower than that of the control ($p < 0.05$) but were not different from each other ($p > 0.05$). This result suggested that both edible coatings displayed similar effects in inhibiting overall colour changes in cherry tomatoes during storage. However, the determination coefficient of the linear regression line of samples coated with SPFG 1:6 was relatively low (0.6673). This was attributed to the fluctuating ΔE* up until day 12 of storage. This fluctuation could be caused by several factors including inaccurate colour measurement or the ununiform colour of fruits.

4. Conclusion

Commercial liquid chitosan and sugar palm fruit served as an effective edible coating. The best formulation of sugar palm fruit edible coating in the present study was a mixture of sugar palm fruits and water at a ratio of 1:6 added with 1% glycerol (SPFG 1:6). Chitosan and SPFG 1:6 managed to maintain the quality of cherry tomatoes and extend their shelf life up to 18 days at room temperature. Cherry tomatoes coated with chitosan and SPFG 1:6 displayed significantly slower weight loss, pH changes, and colour changes (L*, a*, b*, and ΔE* values) compared to the uncoated samples. Commercial liquid chitosan and SPFG 1:6 as edible coating showed the same effectiveness in delaying weight loss, pH, and colour changes ($p > 0.05$) in cherry tomatoes.

Conflict of interest

The authors declare no conflict of interest.

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