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The Effect of Edible Coatings (Spirulina and Chitosan) on the Quality and Shelf Life of Starfruit (*Averrhoa carambola* L. cv. B10) Throughout Storage

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ABSTRACT

The edible coating is one of the preservation methods widely applied by food industries as it is beneficial in suppressing respiration, minimising moisture loss, and reducing food wastage. This study investigates the effects of edible coating (*Spirulina platensis* and chitosan) on the quality and shelf life of B10 throughout storage at room temperature 27°C. The quality analysis of colour (L*, a*, b*, and hue), browning index, fresh weight and physical appearance were evaluated on days 0, 4, 8, 12, and 14. There was a significant difference for all quality analyses between storage days ($p < 0.05$). The physical appearance showed that at day 8, B10 coated with spirulina maintained the greenish colour while chitosan-coated and controlled turned the fruit bright yellowish, indicating ripening. Control samples were observed to have major browning at day 12, whereas samples coated with spirulina and chitosan only showed early signs of browning. Samples with spirulina coating have the least a* (greenness-redness) and b* (blueness-yellowness) values, which showed that spirulina was able to slow down the ripening process in comparison to chitosan and control ($p < 0.05$). For the hue value, samples with chitosan coating showed the least colour changes ($p < 0.05$), followed by spirulina and control with 9.04, 9.43, and 30.82°, respectively. It proved that coated samples provide the best results in slowing

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down the colour changes and browning of the carambola compared to the control. Besides, the regression analysis resulted in a good fitness (R^2 near 1) for browning and weight loss analysis for all coatings, which were agreed to be reliable and had a good predictive indicator power when the storage days were extended. Hence, these results would be potentially useful for the fresh produce industry to prolong the shelf-life of B10 during distribution, transportation, and commercialisation.

Keywords: Carambola, chitosan, colour, quality, regression analysis, shelf-life, *Spirulina platensis*, weight loss

INTRODUCTION

Averrhoa carambola L. cv. B10 is a member of oxalidaceae with star-shaped and greenish-waxy skin during unripe, which turns yellowish during ripening. The flesh and skin are crisp and juicy, while the amount of oxalic acid content mostly influences the taste of the fruit. Consumers like starfruit due to its sweet and sour taste; it also contains abundant antioxidants such as carotenoids, vitamin C, and vitamin E (Gol et al., 2015). Malaysia is the main producer and exporter of carambolas. This fruit is exported to Europe, such as the Netherlands, France, Switzerland, Canada, and other countries in Asia, such as Singapore and Hong Kong, with annual mean export values of RM 24 million (Ibrahim, 2019). It makes carambola one of Malaysia's leading exports that help increase economic growth.

However, due to the unstable internal environment and temperature along the supply chain, the fruits will be exposed to mechanical injuries, microbial attacks, and pathogen contamination. The quality of starfruit can be easily degraded due to the high moisture content level, which will lead to spoilage (Gol et al., 2015). Benkeblia (2018) reported that green and yellow starfruit are easily damaged and can easily bruise. It was also reported that, when starfruit was stored at 16 and 25°C, necrotic lesions, browning, and shrivelling of the ribs appeared at two and three weeks of the storage, respectively. The outbreak of foodborne illness caused by the microbial attack on the fruit can harm consumers as the fruit is often eaten raw (Warriner et al., 2009). Full attention is needed from the producer, storage operator, processor, and retailer when handling the postharvest fruit to maintain the quality and lengthen the shelf-life to reduce waste and food loss (Mahajan et al., 2014).

Various postharvest physical, chemical, and gaseous treatments can be applied to maintain the fresh-like quality without changing the nutritional value of fresh produce. The food industry widely uses physical treatment such as coating, and it has proven its capability of improving food quality and prolonging shelf-life (Lin & Zhao, 2007). The edible coating improves mechanical strength barrier properties and controls the food components' mass transfer (Khwaldia et al., 2004). It can control the gas exchange and oxidation of food products. Besides, specific properties of the edible coating are accountable for decelerating the organic vapour, such as solvent and/or aroma; water vapour; solutes, such as salts,

lipids, food additives and pigments; and gaseous such as carbon dioxide, oxygen, and nitrogen (Kumar & Neeraj, 2019).

There are a few edible coatings: lipid-based, polysaccharide-based, and protein-based. Chitosan coating is a polysaccharide-based coating made from the shell component of crustaceans. It has shown effectiveness in decreasing weight loss, delaying ripening and changes in colour, titratable acidity, and pH and improving the texture of frozen-thawed strawberries (Han et al., 2004). According to Vargas et al. (2006), chitosan can enhance antimicrobial activity and improve water vapour resistance, thus preserving the quality of strawberries better than the uncoated samples. For application on carambola, 0.3% of chitosan obtained significant results in maintaining the quality of carambola as it is proven to delay weight loss, decay percentage, titratable acidity, pH, total soluble solid, sugar accumulation, pigment degradation, and preserving higher concentration of total phenolics content besides excellent in inhibiting enzyme activity (Gol et al., 2015). Despite this, a higher concentration of chitosan in the coating solutions increased anaerobic respiration, followed by rises in fruit weight loss. In another study, chitosan coating was concluded to have good antibacterial and antifungal properties that could minimise bacteria and pathogen attacks and help slow down decay (Kerch, 2015).

Other than chitosan, *Spirulina platensis*, blue-green microalgae is developed to improve the productive performance of the cultivated plant and fresh produce, such development of structural biofilms for fruits coating during postharvest (Byantara & Dianursanti, 2021). Its protein-based coating is safe to consume as a nutritional supplement due to its chemical properties, including phytohormone, antibacterial, and antifungal compounds. De Oliveira et al. (2020) reported in the previous study that 1% *S. platensis* was able to slow down the colour changes and maintained sugar levels and ascorbic acid content while reducing the astringency after taste of carambola in comparison to that 0, 2, 3, and 4% of coating concentration. A study of guar-based edible coating with *S. platensis* and *Aloe vera* extract on mango by Ebrahimi and Rastegar (2020) showed that the coating with spirulina shows significant results in higher firmness and improving the bioactive compound (ascorbic acid, phenol, and flavonoids) throughout storage in comparison to control (uncoated) samples, thus help in maintaining the quality and further the shelf-life.

However, there is a lack of study on *S. platensis* and chitosan coatings on carambola B10. Thus, the effect of edible coatings (*S. platensis* and chitosan) on the quality and shelf-life of carambola B10 is determined in this study.

MATERIALS AND METHODS

Sample Preparation

Starfruit (*Averrhoa Carambola* L. cv. B10) index 2 was freshly plucked from the same tree early in the morning before being transported from Kuala Pilah, Negeri Sembilan, Malaysia to Universiti Putra

Malaysia (UPM), Serdang, Selangor by car in a three-hour journey. Starfruits, index 2, were harvested around 50 to 55 days after the fruit sets. Samples were carefully sorted to ensure uniformity in colour, size, and maturity with approximately no defect. No defect means the fruit must be free from pest attack and any bruise due to mechanical injury or limited to three or below spots ($n \leq 3$) for each fruit. The samples were washed with 0.05% sodium hypochlorite (NaOCl, Systerm, Malaysia) before coating and air dried on the drying racks. Three sets of samples (including control) were prepared, and each set contained three replications.

Preparation of Spirulina and Chitosan Coatings

Spirulina coating solution was prepared following the method by Cardoso et al. (2017). A total of 4% of starch (Systerm, Malaysia), 0.66% spirulina powder (JoyMix, Malaysia), and 0.66% gelatine (Halagel, Malaysia) were added into a solution containing 1% of glycerol (Systerm, Malaysia) and 93% of distilled water. The solution was heated on a heating plate and stirred for 15 min until a boiling point was reached. The coating was covered with the stretch film packaging wrap and was left at room temperature (26 ± 1°C) to reach homogeneity.

The chitosan coating solution was prepared following the method by Gol et al. (2015). The 0.3% (w/v) of chitosan coating solution was prepared by adding 0.3 g of chitosan powder (Chemiz, Malaysia) into 100 ml of distilled water and 0.5 ml (v/v) of glacial acetic acid (R&M Chemicals, Malaysia). The 0.75% of glycerol monostearate (EvaChem, Malaysia) was then mixed into the solution, which acts as a plasticiser to enhance the flexibility and strength of the chitosan coating. A magnetic stirrer was used to constantly stir the solution at room temperature (26 ± 1°C) for 24 hr to achieve complete dispersion. Then, 1 N of sodium hydroxide (ORC Chem Technologies Sdn. Bhd., Malaysia) was added until the pH reached 5.6 and lastly, 0.1 ml Tween 80 (EvaChem, Malaysia) was inserted to stabilise the mixtures.

The fruit samples were then directly dipped into the spirulina and chitosan coating for 2 min, and samples dipped into distilled water served as control. The samples were placed on the cooling racks and let air dried at 26 ± 1°C before being transferred into a box with tissue paper padding at the bottom. Each sample was wrapped with tissue paper to avoid physical contact between one fruit with another. Samples were left at room temperature (26 ± 1°C) until the end of storage days. The coated fruits were subjected to changes throughout storage, and the physical appearance, colour, and fresh weight were observed at days 0, 4, 8, 12, and 14.

Physical Appearance

An image of the samples was taken inside the black box. The LED light ring was placed on top of the box with the light setting of power 12 W, white colour, outer diameter 26 cm, and inner diameter 20 cm. Images were taken using a digital camera

with a fixed setting (Table 1). The images were taken on days 0, 4, 8, 12, and 14. The physical appearance of the samples was observed.

Table 1
Digital camera setting for a physical image of B10

Options	Settings
Megapixels	12 MP
Aperture size	F1.8
Focal length	26 mm
Optical zoom	1.7x
Shutter speed	½ s
Flash	Off
Focus pixel	Autofocus

Colour

The colour of the starfruits was measured at three points (a top, middle, and bottom) using a Minolta Chroma meter CR-400 (ECMinolta, Japan) and the average values were taken. The value of L*, a*, b*, hue, and browning index was calculated. A positive L* value indicates lightness, while a negative L* reading represents darkness. The a* value represents redness to greenness (redness is towards the positive value while greenness is towards the negative value). Besides, the b* value shows yellowness to blueness (yellowness is towards the positive value while blueness is towards the negative value). The hue value was calculated to represent the colour changes of the fruit where the result of 0° = red purple, 90° = yellow, 180° = blue-green, and 270° = blue. The hue value was calculated using Equation 1. The browning of the sample during storage was carried out by calculating the browning index (BI) shown in Equation 2.

$$\text{Hue angle, } \theta \text{ value} = \tan^{-1} |b^*/a^*| \quad \text{(Equation 1)}$$

$$\text{Browning index (BI)} = [100\ (x - 0.31)] / 0.17 \quad \text{(Equation 2)}$$

where, $x = (a^* + 1.75\ L^*) / (5.645\ L^* + a^* - 0.3012\ b^*)$ according to Ruangchakpet and Sajjaanantakul (2007).

Fresh Weight Loss

The fresh weight of the samples was taken using an analytical weighing balance (OHAUS Pioneer, USA). The percentage of fresh weight loss was calculated by Equation 3.

$$W_{loss} = ([W_{initial} - W_{final}]/W_{initial}) \times 100\% \quad \text{(Equation 3)}$$

W_{loss} is the weight loss in unit percentage, $W_{initial}$ is the initial sample weight in unit gram (g), and W_{final} is the final weight of the samples in unit gram (g).

Statistical Analysis

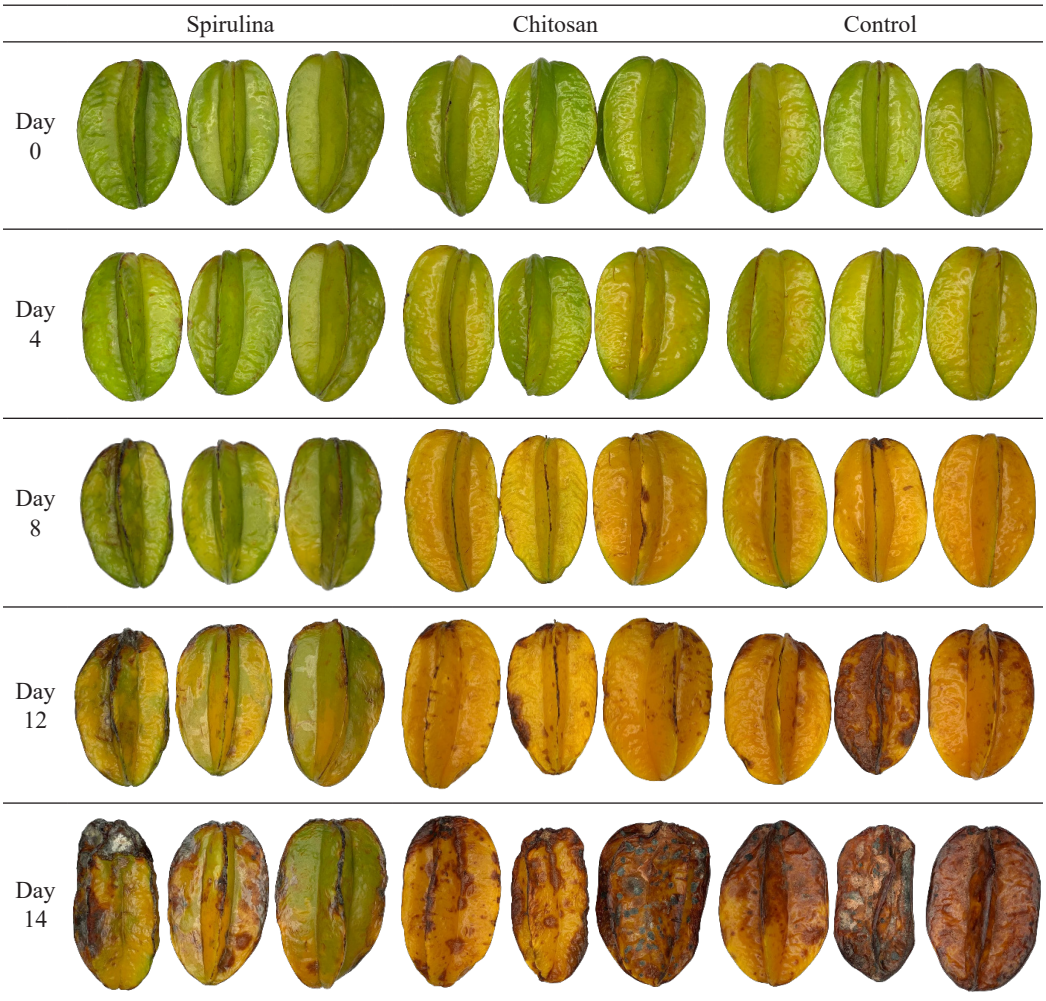
Analysis of variance (ANOVA) was performed using RStudio (version 4.1.2) statistical tools to compare the mean difference between groups. The post hoc test was performed using Tukey's honestly significant difference (HSD) to find the least significant difference ($p < 0.05$) between the compared groups. Linear regression used the first-order kinetic model to observe the relationship between experimental and theoretical data for all the quality tests.

RESULTS AND DISCUSSION

Physical Appearance

The physical appearance of the fruits is the most important quality attribute of fresh and minimally processed produce, where consumers' primary concerns are the size, colour, and defects on the skin finish (Aked, 2000). Spirulina coating maintained the greenish colour, while chitosan coating and control had turned bright yellowish on day 8 of storage (Table 2). The brownish spot on the fruit surface was believed to be an oxidative browning reaction polyphenol oxidase (PPO) oxidises phenolic content into melanin, a brown pigment (Ding & Yap, 2014). The control sample had developed major browning on the skin of the carambola at day 12, besides spirulina and chitosan coatings only showed

Table 2
The physical appearance of B10 coated with 0.66% of spirulina and 0.3% of chitosan coating throughout storage days 0, 4, 8, 12, and 14



early signs of browning development. Spirulina maintained the greenish colour and minimised browning until day 12 but had shown signs of decay compared to chitosan. It showed that spirulina could slow down ripening by minimising colour changes of the carambola but had a poor mechanical barrier, which was susceptible to microbial attack. The control showed major decay on day 12, and the vigorous result showed on day 14 to all samples. Microbial growth on the fruit was due to the decay relative to the gradual respiration and high production of ethylene gas resulting from ripening (Mahajan et al., 2014). According to Butler et al. (1996), polysaccharide properties in chitosan coating act as a good mechanical barrier that helps decrease decay and prevent pathogen infection.

Colour

There were significant differences for L* values in all treatments between the storage days of B10 ($p < 0.05$), and it showed a decrease in the trend as the storage days increased (Figure 1). The lightness (L*) ranged from 0 to 100, while lower values indicate darker colour (Ding & Yap, 2014). However, there was no significant difference ($p > 0.05$) in L* values between coated and uncoated samples on the final day of storage. On the other hand, a* value (redness-greenness) and b* value (yellowness-blueness) showed significant differences ($p < 0.05$) between coatings and storage days. The a* value increased (to redness) as the storage days increased because the ripening process took place. Spirulina coating had the least changes of a* value from the initial to the final storage days, followed by chitosan and control, which proved that spirulina could slow down the ripening process compared to chitosan and control. Suhaimi et al. (2021) agreed that starfruit coated with pectin (PE), maltodextrin (M), and 100 ppm sodium chloride (SC) mixtures had maintained the greenness (positive a*) value ($p < 0.05$) compared to uncoated starfruit. On the other hand, the b* value increased towards intense-yellowish colour, but spirulina had the least difference in b* value from day 0 to day 14, which is 6.36, 18.3, and 9.85 for spirulina, chitosan, and control, respectively (Zaki et al., 2012) supported that slowly increased in the b* values were obtained by the carambola coated with chitosan: stearin compared to uncoated carambola.

For the hue value, chitosan coating had the least colour changes ($p < 0.05$), followed by spirulina and control with the value of 9.04, 9.43, and 30.82°, respectively (Figure 2). The results proved that samples with coatings could minimise colour changes compared with control samples throughout storage days. Colour changes in fruits could be due to dehydration and moisture loss caused by the nonenzymatic browning, caramelisation, and denaturation of proteins in the fruit (Assis & Britto, 2014). A similar result was obtained from the previous study, where samples coated with pectin, maltodextrin, and 100, 200, and 300 ppm of sodium chloride recorded higher hue values compared to control samples due to the coating properties that were able to

reduce ripening process of fruits (Suhaimi et al., 2021). In line with the physical appearance result, there was a significant difference ($p < 0.05$) in the browning index between coated samples and the control. On day 14, spirulina and chitosan coating obtained a low browning index of 52.08 and 98.53, respectively, compared to the control, 107.20. There was also a significant difference ($p < 0.05$) between the browning index and storage days (Figure 3). In the study of strawberries coated with *Aloe*

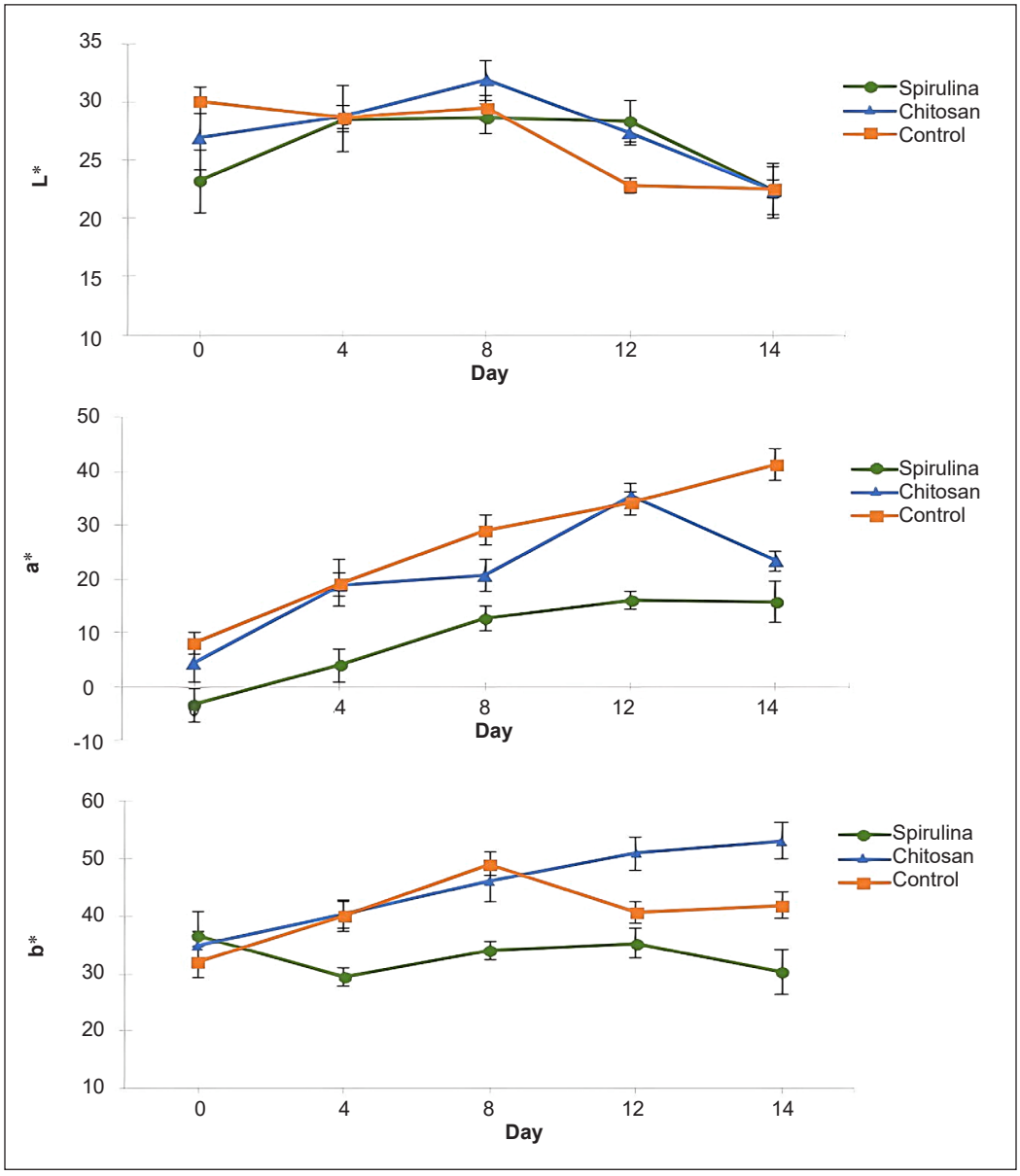


Figure 1. L* a* b* results for B10 coated with 0.66% spirulina and 0.3% chitosan at days 0, 4, 8, 12, and 14 of the storage days

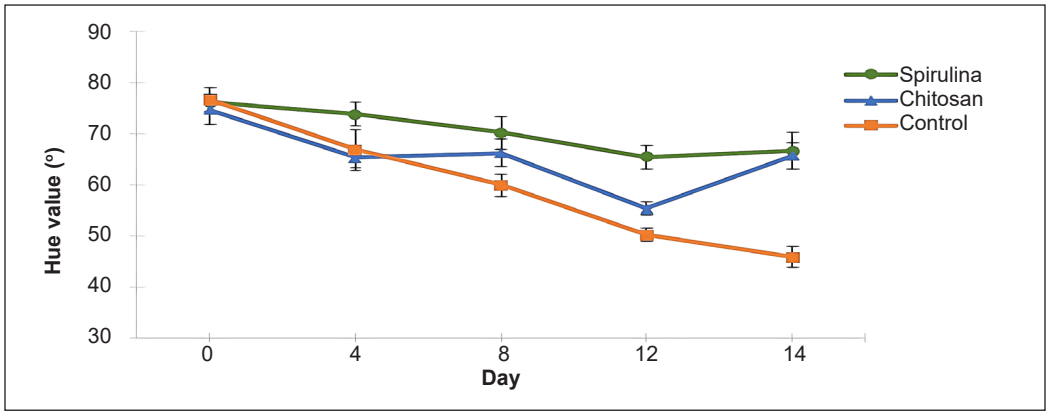


Figure 2. Hue values for B10 coated with 0.66% spirulina and 0.3% chitosan at days 0, 4, 8, 12, and 14 of the storage days

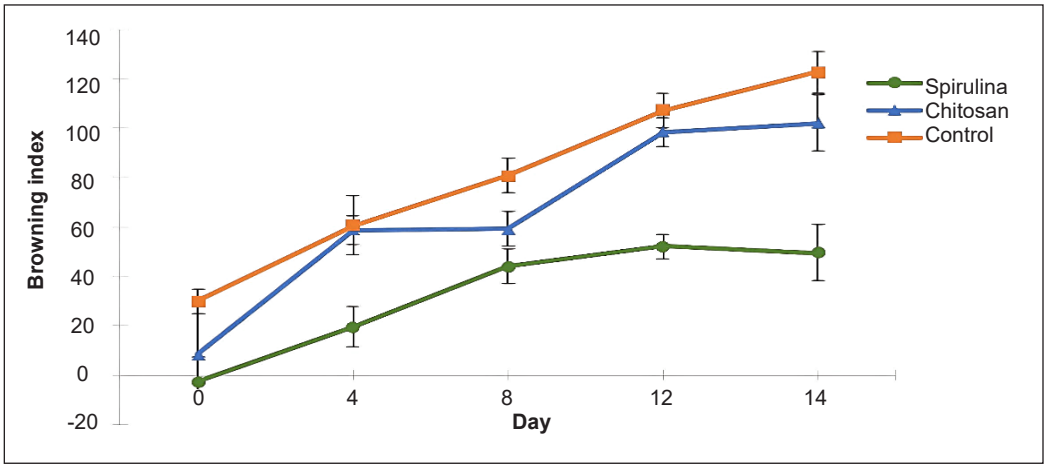


Figure 3. Browning index for B10 coated with 0.66% spirulina and 0.3% chitosan at days 0, 4, 8, 12, and 14 of the storage days

vera, uncoated ripe strawberries tend to become darker, less vivid, and browning compared to coated strawberries (Nasrin et al., 2017). It shows that coated fruits can delay oxidative browning, thus improving the quality.

Fresh Weight Loss

The percentage of fresh weight loss during storage is $p < 0.05$, while there was no significant difference in fresh weight loss of starfruit between different coatings (Figure 4). The mean weight loss showed an increase corresponding with storage days. It showed that spirulina coating had lower water vapour permeability properties than chitosan, resulting in reduced transpiration and weight loss (Hassan et al., 2018). It was agreed by Rastegar and Atrash (2021) that samples coated with spirulina with sodium alginate had resulted in low water loss compared to the uncoated sample of

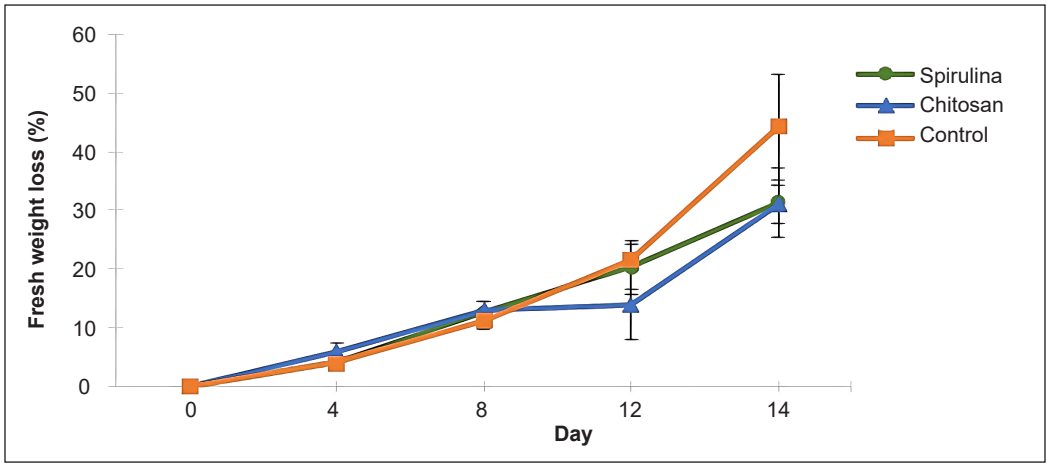


Figure 4. Fresh weight loss (%) for B10 coated with 0.66% spirulina and 0.3% chitosan at days 0, 4, 8, 12, and 14 of the storage days

mango fruit in cold storage. Cardoso et al. (2017) also supported that bell pepper incorporated with spirulina had lower mass loss throughout 14 days of storage. The study of carambola from Karamsad, a village of Anand District, Gujarat, India, proved that carambola coated with 0.3% chitosan had the least weight loss ($p < 0.05$) compared to gum arabica and alginate coatings due to its strong barrier properties in minimising the moisture loss (Gol et al., 2015).

Regression Analysis

The a* and b* were regressions of coefficients, while R^2 was the coefficient of determination obtained from linear regression analysis (Table 3). The range of R^2 values in all samples was from 0.16 to 0.99. Browning index and weight loss analysis obtained significant results ($p < 0.05$) for the determination coefficient at all coatings with $R^2 > 80\%$. It showed that the samples had a good correlation between models and experimental data. Thus, it could access the predictive power of the sampling trend when storage is extended (Ozili, 2022). Besides, low R^2 values such as L* for chitosan coating and b* for control samples indicate a poor relationship between the dependent variable (L* or b*) and the independent variable (storage days).

Furthermore, R^2 values for quality tests of a* and hue angle on chitosan coating were the lowest compared to spirulina and control samples. It might be due to the internal reaction, such as initiating the metabolic reaction in the chitosan-coated sample, which led to drastic changes in the colour throughout storage corresponding to the data obtained in the colour analysis. Rahman et al. (2013) reported in the previous study that papaya stored at 30°C encountered an initiation of anaerobic respiration rate, which caused a sudden increase in the respiratory quotients that were an indication of fermentation threshold, which affected the low R^2 value.

Table 3
The regression coefficient for analysis of L, a*, b*, hue angle, browning index, and weight loss for B10 coated with 0.66% spirulina and 0.3% chitosan*

Quality analysis	Coating	Regression coefficients		R^2
		a*	b*	
L*	Spirulina	24.878	0.386	0.68
	Chitosan	29.333	-0.241	0.16
	Control	31.143	-0.579	0.78
a*	Spirulina	-1.861	1.431	0.94*
	Chitosan	8.299	1.616	0.69
	Control	9.284	2.247	0.99*
b*	Spirulina	32.028	0.154	0.87
	Chitosan	35.112	1.315	0.99*
	Control	36.197	0.602	0.32
Hue angle	Spirulina	76.349	-0.775	0.95*
	Chitosan	72.022	-0.861	0.51
	Control	76.400	-2.175	0.99*
Browning index	Spirulina	2.716	3.921	0.91*
	Chitosan	17.034	6.368	0.92*
	Control	31.413	6.426	0.99*
Weight loss	Spirulina	-2.606	2.144	0.94*
	Chitosan	-1.371	1.864	0.83*
	Control	-5.114	2.804	0.82*

Note. The regression analysis was significant ($p < 0.05$), which indicates that the changes in predicted values were correlated with the changes in the experimental variable

CONCLUSION

By observing the samples' physical appearance, spirulina coating maintained the greenish colour, while chitosan-coated and control samples had turned yellowish on day 8. Despite this, spirulina and control started to decay on day 12, which showed that spirulina could reduce ripening but had a poor mechanical barrier compared to chitosan. Immense browning appeared on the control sample, while an early sign of browning had only shown on spirulina and chitosan coatings at day 12 with the value of 52.08, 98.53, and 107.20 BI, respectively, with symptoms of decay and necrotic lesion. The carambola's lightness (L*) decreased while a* and b* increased in values throughout storage. In addition, coated samples resulted in a lower intensity of hue angle, which were 9.04 and 9.43° for chitosan and spirulina coatings, respectively, compared to control with the value of 30.82°. Samples coated with spirulina showed the least change at a*, b*, and hue angle analysis compared to chitosan and control samples. Gradual weight loss

($p < 0.05$) was determined for all samples throughout storage, but the uncoated sample exhibited the highest weight loss on the final storage day compared to the coated samples. These proved that the coated samples could minimise physical and colour change, including weight loss relative to the storage days ($p < 0.05$). Browning and fresh weight loss showed better fitness with the independent variable (storage days) with the significant value ($p < 0.05$), $R^2 > 80\%$ in the regression analysis. Hence, these results would have the potential for commercialisation and exports between short-distance regions due to edible coatings' performance in maintaining quality and prolonging the shelf-life of the fruits at 27°C. Further studies on the storage of carambola under low temperatures would be further conducted to improve the export quality of carambola between distant freight.

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REFERENCES

Aked, J. (2000). Fruits and vegetables. In D. Kilcast & P. Subramaniam (Eds.), *The stability and shelf-life of food* (pp. 255–278). Woodhead Publishing Limited.

Assis, O. B. G., & de Britto, D. (2014). Review: Edible protective coatings for fruits: Fundamentals and applications. *Brazilian Journal of Food Technology*, *17*(2), 87–97. https://doi.org/10.1590/bjft.2014.019

Benkeblia, N. (2018). Unlocking the full potential of carambola (*Averrhoa carambola* L.) as a food source: Botany, growing, physiology and postharvest technology. In C. L. Beckford (Ed.), *Agriculture, food, and food security: Some contemporary global issues* (pp. 131–158). Nova Science Publisher.

Butler, B. L., Vergano, P. J., Testin, R. F., Bunn, J. M., & Wiles, J. L. (1996). Mechanical and barrier properties of edible chitosan films as affected by composition and storage. *Journal of Food Science*, *61*(5), 953–955. https://doi.org/10.1111/j.1365-2621.1996.tb10909.x

Byantara, P., & Dianursanti. (2021). Utilization of *Spirulina platensis* microalgae as edible coating to maintain quality of fresh strawberry (*Fragaria* sp.). In *AIP Conference Proceeding* (Vol. 2344, No 1, p. 020016). AIP Publishing. https://doi.org/https://doi.org/10.1063/5.0047579

Cardoso, T., Demiate, I. M., & Danesi, E. D. G. (2017). Biodegradable films with *Spirulina platensis* as coating for Cambuci peppers (*Capsicum* sp.). *American Journal of Food Technology*, *12*(4), 236–244. https://doi.org/10.3923/ajft.2017.236.244

de Oliveira, L. M., de Oliveira, Á. M. F., Araújo, R. H. C. R., Dias, G. A., de Medeiros Teodósio, A. E. M., de Lima, J. F., da Silva Barbosa, L., & Guedes, A. W. (2020). *Spirulina platensis* coating for the conservation of pomegranate. *AIMS Agriculture and Food*, *5(1)*, 76–85. https://doi.org/10.3934/agrfood.2020.1.76

Ding, P., & Yap, S. L. (2014). Browning assessment methods and polyphenol oxidase in UV-C irradiated Berangan banana fruit. *International Food Research Journal*, *21*(4), 1667–1674.

Ebrahimi, F., & Rastegar, S. (2020). Preservation of mango fruit with guar-based edible coatings enriched with *Spirulina platensis* and *Aloe vera* extract during storage at ambient temperature. *Scientia Horticulturae*, *265*, 109258. https://doi.org/10.1016/j.scienta.2020.109258

Gol, N. B., Chaudhari, M. L., & Rao, T. V. R. (2015). Effect of edible coatings on quality and shelf life of carambola (*Averrhoa carambola* L.) fruit during storage. *Journal of Food Science and Technology*, *52*, 78–91. https://doi.org/10.1007/s13197-013-0988-9

Han, C., Zhao, Y., Leonard, S. W., & Traber, M. G. (2004). Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (*Fragaria* x *ananassa*) and raspberries (*Rubus ideaus)*. *Postharvest Biology and Technology*, *33*(1), 67–78. https://doi.org/10.1016/j.postharvbio.2004.01.008

Hassan, B., Chatha, S. A. S., Hussain, A. I., Zia, K. M., & Akhtar, N. (2018). Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review. *International Journal of Biological Macromolecules*, *109*, 1095–1107. https://doi.org/10.1016/j.ijbiomac.2017.11.097

Ibrahim, A. (2019, April 7). MARDI perkenal belimbing hibrid Bintang Mas [MARDI introduces Bintang Mas hybrid starfruit]. *Berita Harian*. https://www.bharian.com.my/berita/nasional/2019/04/549903/mardi-perkenal-belimbing-hibrid-bintang-mas

Kerch, G. (2015). Trends in food science & technology chitosan films and coatings prevent losses of fresh fruit nutritional quality: A review. *Trends in Food Science and Technology*, *46*(2), 159–166. https://doi.org/10.1016/j.tifs.2015.10.010

Khwaldia, K., Perez, C., Banon, S., Desorby, S., & Hardy, J. (2004). Milk proteins for edible films and coatings. *Critical Reviews in Food Science and Nutrition*, *44*(4), 239–251. https://doi.org/10.1080/10408690490464906

Kumar, N., & Neeraj. (2019). Polysaccharide-based component and their relevance in edible film/coating: A review. *Nutrition and Food Science*, *49*(5), 793–823. https://doi.org/10.1108/NFS-10-2018-0294

Lin, D., & Zhao, Y. (2007). Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive Reviews in Food Science and Food Safety*, *6*(3), 60–75. https://doi.org/10.1111/j.1541-4337.2007.00018.x

Mahajan, P. V., Caleb, O. J., Singh, Z., Watkins, C. B., & Geyer, M. (2014). Postharvest treatments of fresh produce. *Philosophical Transactions of the Royal Society: A Mathematical, Physical and Engineering Sciences, 372*(2017), 20130309. https://doi.org/10.1098/rsta.2013.0309

Nasrin, T. A. A., Rahman, M. A., Hossain, M. A., Islam, M. N., & Arfin, M. S. (2017). Postharvest quality response of strawberries with *Aloe vera* coating during refrigerated storage. *Journal of Horticultural Science and Biotechnology*, *92*(6), 598–605. https://doi.org/10.1080/14620316.2017.1324326

Ozili, P. K. (2022). The acceptable R-Square in empirical modelling for social science research. In *Social research methodology and publishing results: A guide to non-native english speakers* (pp. 134-143). IGI Global. https://doi.org/10.2139/ssrn.4128165

Rahman, E. A. A., Talib, R. A., Aziz, M. G., & Yusof, Y. A. (2013). Modelling the effect of temperature on respiration rate of fresh cut papaya (*Carica papaya* L.) fruits. *Food Science and Biotechnology*, *22*, 1581–1588. https://doi.org/10.1007/s10068-013-0254-y

Rastegar, S., & Atrash, S. (2021). Effect of alginate coating incorporated with spirulina, *Aloe vera* and guar gum on physicochemical, respiration rate and color changes of mango fruits during cold storage. *Journal of Food Measurement and Characterization*, *15*, 265–275. https://doi.org/10.1007/s11694-020-00635-6

Ruangchakpet, A., and Sajjaanantakul, T. (2007). Effect of browning on total phenolic, flavonoid content and antioxidant activity in Indian

gooseberry (*Phyllanthus emblica* Linn.). *Agriculture and Natural Resources*, *41*(5), 331–337.

Suhaimi, N. I. M., Ropi, A. A. M., & Shaharuddin, S. (2021). Safety and quality preservation of starfruit (*Averrhoa carambola* L.) at ambient shelf life using synergistic pectin-maltodextrin-sodium chloride edible coating. *Heliyon*, *7*(2), e06279. https://doi.org/10.1016/j.heliyon.2021.e06279

Vargas, M., Albors, A., Chiralt, A., & González-Martínez, C. (2006). Quality of cold-stored strawberries as affected by chitosan-oleic acid edible coatings. *Postharvest Biology and Technology*, *41*(2), 164–171. https://doi.org/10.1016/j.postharvbio.2006.03.016

Warriner, K., Huber, A., Namvar, A., Fan, W., & Dunfield, K. (2009). Recent advances in the microbial safety of fresh fruits and vegetables. In *Advances in food and nutrition research* (Vol. 57, pp. 155–208). Elsevier Inc. https://doi.org/10.1016/S1043-4526(09)57004-0

Zaki, N. H. M., Som, H. Z. M., & Haiyee, Z. A. (2012). Application of palm stearin-chitosan edible coating on star fruits (*Averrhoa carambola* L.). *Malaysian Journal of Analytical Sciences*, *16*(3), 325–334.