Sago starch edible coating retains the organoleptic properties of non-climacteric fruits

Sukuriyati Susilo Dewi[1,*], *Nafi* Ananda Utama[1] and *Dwi* Rimbawati[1]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, Indonesia

Abstract. Non-climacteric fruits, such as cucumber, do not undergo ripening after harvested. However, other metabolic processes such as respiration and transpiration can still occur during transportation and storage. Both metabolic processes result in the decrease of moisture content in cucumber. The adverse effects on fruit with high water loss are poor appearance and shorter shelf life. Thus, postharvest treatments to avoid moisture content decline are crucial and imperative in cucumber. The present study investigated sago starch's optimal concentration and effect as a potential edible coating in non-climacteric fruit (cucumber var. CU 699). A completely randomized design study was used with four different coating treatments: control, 5%, 7.5%, and 10% of sago starch edible coating groups. A hedonic test and color measurement were conducted to evaluate the sensory attributes of the cucumber after ten days of storage. The physicochemical properties of cucumber analyzed to assess the shelf-life include weight loss, hardness, titratable acidity, total soluble solids, and vitamin C content. Sago starch edible coating treatment showed the ability to retain the visual attributes of cucumber and a higher likeness score after the hedonic test compared to control samples.

1 Introduction

Cucumber (*Cucumis sativus* L.) var. CU 699 is a hybridization between the CU 505 (F) and CU 495 (M) varieties, as a product of single cross, intervarietal hybridization by an Indonesia producer of horticulture seeds, PT. Benih Citra Asia. The variety was registered by PT. Benih Citra Asia and verified by the Indonesian Directorate General of Horticulture in the official database in 2010 (Indonesian Directorate General of Horticulture, 2010). The produced fruit by cucumber var. CU 699 is cylindrical, light green with 15-18 cm of length, 5.1 – 5.6 cm diameter, an optimal storage temperature of 24-30 °C, average weight between 245 – 268 grams, and ready to harvest 30 to 35 days after planting. According to the Central Statistics Agency, Indonesia suffered a 5.91% cucumber production decrease in 2022 (444,057 tons) compared to the production in 2021 (471,941 tons) [2]. One of the main concerns in cucumber production is the moisture loss during the distribution and transportation process.

*Corresponding author: dewisusilo@umy.ac.id

The shelf life of cucumber is seven days at room temperature [3]. As a commodity comprised mostly of water (93-97%), its moisture content heavily affects cucumber's storage life. Excess water loss can lead to quality and visual appearance deterioration, including wrinkling and shrinkage of the skin/peel texture [4]. Another change that can happen is the color shift from green to yellow due to sunlight overexposure, resulting in chlorophyll breakdown [5]. Therefore, postharvest treatment is crucial to preserve cucumber quality until the produce reaches the consumer.

Edible coating is a commonly used postharvest technique to extend the shelf life of horticultural commodities. The current study evaluated the potential of sago starch as an affordable alternative for edible coating materials in cucumbers. The sago starch solution is flavorless, colorless, safe to consume, and does not change the commodity's properties; thus, sago starch is a potential edible coating for fruit and vegetables [6]. The sago starch contains a high level of amylose, with 28.84% amylose and 71.16% amylopectin [7]. Due to its hydrophilic characteristics, the edible coating film produced from high amylose starch will have poor mechanical properties and low elasticity [8]. Glycerol was added as a plasticizer to enhance the mechanical properties of sago starch films.

The present study addressed one of the main issues in cucumber marketability. As most cucumber content is water, excessive moisture loss will result in undesirable visual appearance and shorter shelf life. The sago starch was investigated as an alternative, affordable material to produce an edible coating film for maintaining sensorial properties and improving the shelf life of cucumber (*Cucumis sativus* L.) varieties CU 699'.

2 Research method

2.1 Sample preparation

Cucumber (*Cucumis sativus* L.) var. 699 was obtained directly from the farmer fields at Balecatur, Sleman Regency, Yogyakarta, Indonesia (7° 48' 25.9", 110° 17' 37.286"). The fruits were harvested 30 days after planting. Several physical attributes requirement of cucumber in this study include whiteish green skin, having a 7.5 GY (3/4) color index according to Munsell Color Chart for Plant Tissues, 15-16 cm length, 245–268-gram weight with no visible mechanical damage, and free from diseases

2.2 Preparation and application of sago starch edible coating

The study used a local and commercial packaged sago starch powder (HD, Indonesia). To prepare the edible coating, sago starch powder was diluted in 1 L of distilled water according to each sago starch treatment (50, 75, and 100 grams). The solution was stirred using T 25 Digital Ultra Turrax homogenizer (IKA, Germany) for 10 minutes and 1000 rpm at room temperature. Then, the solution was heated with a Bunsen burner until it reached 65 °C before being further mixed with the homogenizer at 1000 rpm. Then, glycerol was gradually added while the solution was on top of the Bunsen burner. The stirring and heating were stopped at a solution temperature of 70 °C.

Before edible coating treatment, the cucumber samples were washed in running water. Then, the samples were dipped in the edible coating solution according to each treatment group (control, 5%, 7.5%, or 10% sago starch) for a minute. The coated samples were air-dried at room temperature and then transferred into a Styrofoam tray with lids. The cucumber samples were stored at room temperature for ten days.

2.3 Observed parameters

A hedonic test and color measurement were performed to evaluate the visual appearance of cucumber with sago starch edible coating. The hedonic test was carried out with panelists on the samples after ten days of storage, while color measurement was done once every two days for ten days.

2.3.1 Hedonic tests

The hedonic analysis was conducted to assess the organoleptic properties of cucumbers using different treatments for sago starch edible coating. The hedonic test can also be used to investigate consumers' acceptability. The test evaluates the likeness scale of panelists on the color, texture, aroma, taste, and overall likeness using a 5-point hedonic scale (Scale: 1-dislike extremely; 2-dislike slightly; 3-neither like nor dislike; 4-like slightly; 5-like extremely.

2.3.2 Color measurements

The analysis was carried out by comparing the peel color of cucumber with the Munsell Plant Tissue Color Chart. The hue, value, and chroma scores were recorded once every two days for ten storage days. The hue score refers to the dominant color of the sample, chrome is the saturation or the strength level of the hue, and the value score shows the lightness level.

2.3.3 Physicochemical analysis

Aside from organoleptic measures, the current study also investigated the quality parameters regarding the shelf life of cucumbers after different sago starch edible coating treatments. Weight loss measurement was carried out every day. At the same time, the hardness, total soluble solids, titratable acidity, and vitamin C level analyses were performed once every two days for ten days of storage.

The cucumber weight was measured once daily and calculated for weight loss by subsiding the weight before and after the current measurement day. The result was expressed in percentages. A texture analyzer was used to penetrate an 8 cm-diameter needle into three different parts of the sample (front, middle, and end) to evaluate the hardness score. The score was recorded in N/mm^2 units.

A refractometer was used to perform the soluble solids analysis in this study. Before every analysis of different samples, the measuring prism was rinsed with a drop of distilled water and wiped with soft tissue. The extracted juice samples were transferred to the clean measuring prism for 1-3 drops. The total soluble solid score obtained was recorded in the °Brix unit.

Samples were extracted for their juice, and 10 mL were transferred into an Erlenmeyer. Then, three drops of 1% phenolphthalein were added to the Erlenmeyer. The solution was titrated using 0.1 N NaOH until the color shifted to pink. The titratable acidity was calculated based on the AOAC (2002).

The vitamin C score was analyzed according to the AOAC (2002). Five grams of samples were diluted in 100 mL distilled water, and then 20 mL of the filtrate was transferred to an Erlenmeyer. Before titration with 0.01 N iodine, 2 mL of 1% amylum was added as a titration indicator. The titration was stopped when the solution turned into stable blue.

2.4 Statistical analysis

This study's data visualization and statistical analysis were performed using R (version 4.1.3) in the RStudio software (version 2023.12.1). The ggradar, ggplot2, and cowplot packages were required to generate the spider graph and plotlines. The meaning significant difference between treatment groups for quality parameters was analyzed using Duncan's Multiple Range Test (DMRT) using the agricolae package.

3 Results and discussion

3.1 Visual appearance measurements

The hedonic test and color measurements were done to evaluate the visual appearance of cucumbers treated with different sago starch edible coatings. In the hedonic test, panelists were asked to answer questions in a form regarding the degree of likeness towards the aroma, color, taste, texture, and overall likeness of the samples. The result of the hedonic test is illustrated in a spider graph (Figure 1).

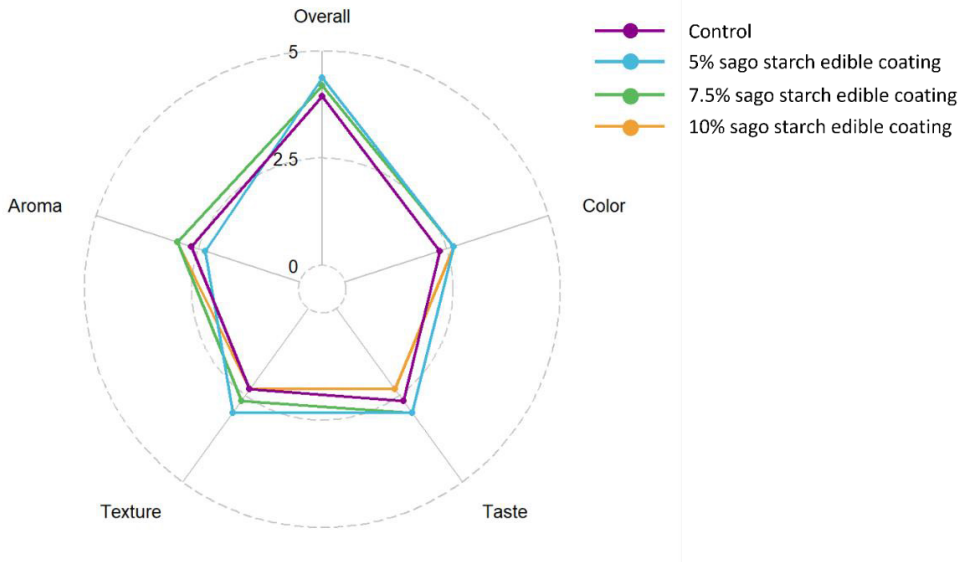

Fig. 1. The result of a hedonic test on the aroma, color, taste, texture, and overall likeness of cucumber treated with different sago starch edible coating after ten days of storage.

Cucumbers treated with sago starch edible coating were preferred compared to control samples. The taste attribute in the control (2.33) was lower than the treated samples, although both scores were neutral and slightly disliked. In individual sensory attributes, the 5% sago starch edible coating was the most liked among the treatment groups. However, most panelists preferred cucumber treated with 7.5% sago starch edible coating (4.38) on overall likeness, while control samples displayed the lowest likeness score (3.94).

The color change of cucumber with different sago starch edible coating treatments was evaluated by comparing the peel color with the Munsell Plant Tissue Color Chart. The result of color measurement is displayed in Table 1.

Table 1. Color measurement result of cucumber treated with different concentrations of sago starch edible coating

Day	Treatments											
	Control			5% sago starch			7.5% sago starch			10% sago starch		
	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
0	7.5 GY	4	4	7.5 GY	4	4	7.5 GY	3	4	7.5 GY	4	4
2	7.5 GY	4	6	7.5 GY	4	4	7.5 GY	4	4	7.5 GY	4	6
4	7.5 GY	4	6	7.5 GY	4	4	7.5 GY	4	4	7.5 GY	4	6
6	5 GY	5	6	7.5 GY	4	6	7.5 GY	4	4	7.5 GY	4	6
8	5 GY	4	6	7.5 GY	5	6	7.5 GY	4	4	7.5 GY	4	6
10	5 GY	5	6	7.5 GY	6	6	7.5 GY	4	6	7.5 GY	7	6
Note: The Munsell Plant Tissue Color Chart was used for comparison for the color measurement.												

The control samples showed the fastest color change from green to yellowish green on the sixth day of storage, as seen in the hue value shift from 7.5 GY to 5 GY. On the contrary, samples treated with sago starch edible coating, regardless of the concentration, had a gradual discoloration from green to light green. The same color value obtained on day 10 of storage on samples with 7.5% sago starch edible coating had already been revealed earlier in other groups. Therefore, it can be concluded that on the last day of storage, samples treated with 7.5% sago starch edible coating exhibited significant peel color retention compared to other treatments.

Samples that received no sago starch edible coating treatment appeared to have a faster color shift than treated samples. Similarly, the control samples were the least liked in the color attribute evaluation of the hedonic test from Figure 1. These results showed a possible association between faster color change and low scores on the hedonic test, particularly the likeness score of the color profile. According to Jang *et al.* (2022), during the storage time of horticulture products, the synthesis development of carotenoid pigment, previously covered by chlorophyll, occurred. Thus, more extended storage will lead to more chlorophyll degradation, and carotenoid becomes cucumber's dominant pigment. Applicating cucumber with sago starch edible coating retains the color shift as the coating can decrease the rate of respiration process and chlorophyll degradation on the skin tissues of cucumber [11]. The findings of this study showed that the 7.5% sago starch edible coating was the optimal concentration to maintain the peel color of cucumber. Research by Suwarda et al. [12] reported that the best water vapor transmission rate was seen on low concentrations of edible film as it can effectively suppress the activity of chlorophyllase enzymes on cucumber.

According to Meng *et al.* [13],the storage life of cucumbers is strongly associated with postharvest discoloration due to the consequent pH decrease and chlorophyll degradation. The research also mentioned that cucumber is highly sensitive towards exogenous ethylene, even at low levels, which can lead to a faster color shift to yellow and tissue damage. Exogenous ethylene plays a significant role in increasing the rate of chlorophyll breakdown without changing or diverting from the original degradation pathway without external treatment of ethylene. Chlorophyll in plants can be degraded to chlorophyllide by chlorophyllase enzyme or pheophytin by losing the center magnesium ions (Mg^{2+}) and

phytol tail. During the catabolic process, total citric acid in the endocarp increases while malic acid declines.

3.2 Physiochemical properties analysis

Among five quality parameters (Figure 2), weight loss and vitamin C level showed mean values that differed between treatment groups; however, samples with no edible coating treatment displayed the significantly lowest weight loss (Figure 2A).

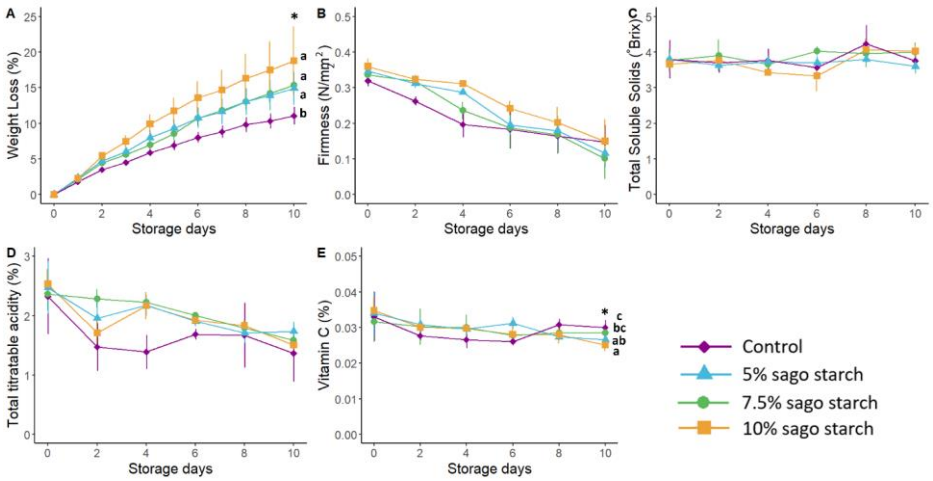

Fig. 2. The weight loss (A), firmness (B), total soluble solids (C), total titratable acidity (D), and vitamin C level (E) of cucumbers with different sago starch edible coating during ten days of storage. On the last storage day, an asterisk (*) marked a significant difference in mean between treatment groups after Duncan's Multiple Range Test (α = 5%). The same alphabetical order marked no significant difference between the values.

Applying 10% sago starch showed the most weight loss percentage (18.8 ± 4.76 %). A study by Kocira *et al.* [14] stated that sago starch has low water retention properties due to its hydrophilic nature. These two characteristics adversely affect the stability of edible film in extending the shelf life of horticulture commodities. On the contrary, research by Lumbantoruan and Yulianti [15] found that higher concentrations of edible coating solution will result in higher levels of soluble particles that can cause frictions and pressures between particles. As a result, a solution with high viscosity will create an edible layer with a very thick film that is difficult to dry when applied to fruits or vegetables. Hence, at the beginning of the analysis, the cucumber will have more initial weight but then experience faster weight loss in the following days.

No significant difference was seen between the hardness of cucumbers with different sago starch edible coating treatments (Figure 2B). Based on a previous study, the decline in hardness in fruits and vegetables is caused by respiration and transpiration [16]. Edible coating is commonly used to retain hardness as it can increase the hydroxyl group in the outer layer and generate a strong interaction between polymer chains to lower gas and water permeability. Thus, water can be retained, and cell wall degradation can be slower [17]. However, in this study, samples with no edible coating treatment (0.15 ± 0.05 N/mm^2) and 10% sago starch edible coating (0.15 ± 0.06 N/mm^2) had similar firmness at the last day of observation.

Figure 2C depicts the total soluble solids of cucumber treated with various concentrations of sago starch edible coating. Samples treated with 5% (4.00 ± 0.26 °Brix) and 10% (4.03 ± 0.15 °Brix) sago starch coating had higher total soluble solids value

compared to control samples (3.75 ± 0.25 °Brix), although no significant difference was seen between treatment groups. Study by Valverde-Miranda *et al.* [18] reported that starch degradation to simple sugars can increase total soluble solids in cucumber. According to research by Amiarsi [19], the starch breakdown to sucrose, glucose, and fructose occurs faster than respiration, which converts glucose to water and energy in non-climacteric fruit. Hence, more sugars were produced compared to those used in respiration. Sugars accumulate in tissues during storage, and the total soluble solids will not change compared to the controls, as indicated in the results of this study.

Similar to the results for total soluble solids, the titratable acidity of cucumber between varied sago starch edible coating treatments displayed no significant difference (Figure 2D). Nevertheless, the titratable acidity of treated samples was higher than control samples (1.37 ± 0.48 %). Samples with 7.5% sago starch edible coating had the highest titratable acidity at 1.74 ± 0.15 %. The decline of titratable acidity is caused by the respiration process, where complex compounds are catabolized to simpler compounds facilitated by substrate obtained from glucose, fructose, sucrose, lipids, organic acids, and proteins [20]. The titratable acidity decreased due to the breakdown of organic acids into water and CO_2 [21].

The vitamin C level of untreated cucumber (0.030 ± 0.002 %) was higher than samples coated with sago starch edible coating regardless of the concentration (Figure 2E). Although 5% sago starch edible coating had a similar vitamin C content of 0.029 ± 0.001 %, the two values were significantly different after statistical analysis. According to research by Tetelepta *et al.* [21], vitamin C loss in cucumbers occurred due to postharvest transpiration during storage. By applying an edible coating, adding an outer layer will act as a barrier to delay oxygen entering the fruit, which can oxidize vitamin C faster [22].

The application of sago starch edible coating did not maintain physicochemical attributes pertaining to fruit ripening on cucumber after ten days of storage. On the other hand, the likeness scale and visual appearance of cucumbers were significantly retained on treated samples compared to the control. As an edible coating film, sago starch can sustain cucumber's organoleptic properties but fails to slow physicochemical changes during storage. Thus, it can be concluded that the edible coating of sago starch can be applied to cucumber to perpetuate the sensory attributes. However, sago starch should not be used solely as an edible film, and additional material is required to maintain the physicochemical properties of cucumber. Further research must investigate which ingredients can be a potential addition to sago starch edible coating.

4 Conclusion and recommendation

Sago starch as an edible coating on cucumber (*Cucumis sativus* L.) var. 699 can sustain the peel color and show a higher likeness score after ten days of storage. The cucumbers applied with 7.5% sago starch edible coating had the highest overall likeness and slowest discoloration. In comparison, cucumbers coated with 5% sago starch displayed the preferred color, taste, texture, and aroma after evaluation using a hedonic test. Nonetheless, no changes in physicochemical properties were retained on cucumber treated with sago starch edible coating at the last observation day. Thus, further research to evaluate the potential supplementary materials to sago starch edible coating should be investigated to improve its properties and decrease physicochemical change rates.

References

1. Indonesian Directorate Generate of Horticulture, List Regist. Hortic. Var. 2 (2010)

2. Indonesian Central Agency of Statistics, *Production of Vegetables Per Regions and Type, 2022* (Jakarta, 2022)
3. Y. Lira, V. Arista, A. Khairunissa, and A. J. Chastelyna, JAGO TOLIS J. Agrokompleks Tolis **3**, 36 (2023)
4. M. Murtiwulandari, D. T. M. Archery, M. Haloho, R. Kinasih, L. H. S. Tanggara, Y. H. Hulu, K. Agaperesa, N. W. Khristanti, Y. Kristiyanto, S. S. Pamungkas, Y. A. Handoko, and G. D. Y. Anarki, Teknol. Pangan Media Inf. Dan Komun. Ilm. Teknol. Pertan. **11**, 136 (2020)
5. C. Patel and J. Panigrahi, Food Chem. **288**, 208 (2019)
6. R. Suwarda, D. Sondari, Nurhafsah, and H. Smith, in *Proc. 1st Int. Conf. Food Agric. Sci. 2022* (AIP Conference Proceedings, Bogor, 2024)
7. F. J. Polnaya, A. A. Huwae, and G. Tetelepta, Agritech **38**, 7 (2018)
8. W. Widaningrum, M. Miskiyah, and C. Winarti, J. Agritech **35**, 53 (2015)
9. AOAC, *AOAC Guidelines for Single Laboratory Validation of Chemical Methods for Dietary Supplements and Botanicals* (2002)
10. S. Jang, G. W. Kim, K. Han, Y. M. Kim, J. Jo, S. Y. Lee, J. K. Kwon, and B. C. Kang, Front. Plant Sci. **13**, 1 (2022)
11. L. A. Handojo, D. Shofinita, G. Evelina, and A. N. Nasution, IOP Conf. Ser. Earth Environ. Sci. **980**, 012046 (2022)
12. R. Suwarda, T. T. Irawadi, P. Suryadarma, and I. Yuliasih, J. Teknol. Ind. Pertan. **29**, 278 (2019)
13. X. Meng, M. Zhang, Z. Zhan, and B. Adhikari, Food Bioprocess Technol. **7**, 693 (2014)
14. A. Kocira, K. Kozłowicz, K. Panasiewicz, M. Staniak, E. Szpunar-Krok, and P. Hortyńska, Agron. 2021, Vol. 11, Page 813 **11**, 813 (2021)
15. P. Lumbantoruan and E. Yulianti, J. Sainmatika **13**, 26 (2019)
16. R. Lufu, A. Ambaw, and U. L. Opara, Postharvest Biol. Technol. **157**, 110982 (2019)
17. S. Katili, B. T. Harsunu, and S. Irawan, J. Teknol. **6**, 29 (2013)
18. D. Valverde-Miranda, M. Díaz-Pérez, M. Gómez-Galán, and Á. J. Callejón-Ferre, Postharvest Biol. Technol. **180**, 111603 (2021)
19. D. Amiarsi, J. Hortik. **22**, 197 (2012)
20. I. A. N. Fauziah and H. Sholihin, Chem. Isola **1**, 49 (2021)
21. G. Tetelepta, P. Picauly, F. J. Polnaya, R. Breemer, and G. H. Augustyn, AGRITEKNO, J. Teknol. Pertan. **8**, 29 (2019)
22. B. Yousuf and A. K. Srivastava, Food Packag. Shelf Life **21**, 100361 (2019)
23. J. W. Creswell, *Research Design : Qualitative, Quantitative, and Mixed Methods Approaches*, 4th ed (Sage Publications, London, 2014)
24. I. Imelda, R. Hidayat, and M. Aritonang, Agrar. J. Agribus. Rural Dev. Res. **8**, 46 (2022)
25. Triyono, M. Fauzan, J. Mu'awanah, and M. Sedek, E3S Web Conf. **316**, 02036 (2021)
26. Food and Agriculture Organization, Fao.Org (2020)