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Effect of CMC Concentration Based on Oil Palm Empty Fruit Bunches and Chitosan Addition on Edible Coating Characteristics on Strawberries

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ABSTRACT

Strawberries are a fruit that is prone to post-harvest damage because it has a high moisture content and soft tissue structure. Carboxymethyl cellulose-based edible coatings from the fibers of empty bunches of oil palm and chitosan have the potential to maintain the quality of strawberries during storage. This study aims to determine the effect of variations in CMC concentration based on Empty Oil Palm Bunches and chitosan on the edible coating characteristics and the quality of strawberries. The study used a factorial experiment design consisting of CMC concentration (1%, 1.5%, and 2%) and chitosan concentration (1%, 2%, and 3%) with two replications. The observed parameters included viscosity, pH, weight loss, discoloration, and organoleptic properties. The data were analyzed using ANOVA followed by the Duncan test at a significance level of 5%. The results showed that the increase in CMC and chitosan concentrations had a significant effect ($p < 0.05$) on the increase in viscosity, with values ranging from 6.05–47.01 cP. The pH value ranges from 5.17–5.48 which indicates that the coating solution is relatively stable. The lowest weight loss was obtained in the 2% CMC treatment with an average value of 24.85%. Organoleptic tests showed that color and texture had a real effect, while the scent did not differ noticeably. The best treatment combination was obtained at the concentration of CMC 1.5% and chitosan 2% because it was able to provide the best edible coating characteristics and strawberry quality during storage.

INTRODUCTION

Indonesia is known as one of the largest oil palm producing countries in the world, with plantations reaching 15.32 million hectares in 2023, of which 59.5% are managed by small plantations, 28.4% by national private companies, and 12.1% by large state plantations (Central Statistics Agency, 2024). The high production of palm oil not only makes a large economic contribution, but also produces a significant volume of solid waste, one of which is empty oil palm bunches which reach around 22-23% of every ton of fresh fruit bunches processed.

The use of empty oil palm bunches as solid waste is still low, this is in line with research Deswati (2018) that only about 10% is used for boiler fuel or compost, while the rest has not been treated to the maximum, causing environmental problems. Chemically, empty oil palm bunches have the main content in the form of lignocellulose consisting of cellulose, hemicellulose, lignin, fiber and water content as well as extractive substances (Chairunnisa *et al.*, 2024). The content component shows that empty oil palm bunches have the potential to be developed into value-added products and can reduce waste.

Edible coating serves as a protective layer on food surfaces that inhibits the growth of microorganisms (Dewi et al., 2019). One of the biopolymers that is widely used as a basic material for edible coating is carboxymethyl cellulose (CMC) which is a cellulose derivative that has water-soluble properties, high viscosity and is able to form a stable film so that it has the potential to be used as an ingredient in food products (Parid et al., 2018). Palm oil empty bunch cellulose as a raw material for CMC plays an important role in providing mechanical strength obtained through the chemical modification process (Dimawarnita & Faramitha, 2019). CMC-based edible film coating has the ability to form a good film but the affinity with water is very high due to the large number of hydroxyl and carboxyl groups in the CMC structure, so CMC film tends to have a high value of High Water Vapor Transmission Rate (WVTR) and is less effective as a moisture inhibitor (Marpaung et al., 2015). Therefore, additives in the form of chitosan are necessary in the manufacture of edible coatings due to its properties of Former Film of its good, waterproof and natural antimicrobial activity (Wardhani et al., 2023; Alhuur et al., 2020)) .

Several previous studies have reported the use of synthetic CMC and chitosan as edible coating materials, but research on the use of CMC based on Empty Oil Palm Bunches combined with chitosan in strawberries is still limited. In addition, the effect of variations in CMC concentration based on empty oil palm bunches and chitosan on edible coating characteristics and strawberry quality during storage has not been comprehensively studied. This study utilizes empty oil palm bunch waste as a source of carboxymethyl cellulose (CMC) combined with chitosan in edible coating formulations to maintain the physical and sensory qualities of strawberries during storage. Therefore, this study was conducted to determine the effect of variations in CMC concentration based on empty oil palm bunches and the addition of chitosan on the edible coating characteristics of strawberries.

This research is expected to provide information on the optimal composition of film-forming materials to produce edible coatings with good characteristics. In addition, this research is also expected to support the use of empty oil palm bunch waste as raw materials for value-added and environmentally friendly products.

RESEARCH METHODS

This study uses Randomized Complete Block Design (RCBD) with two factors. The first factor is the variation in CMC concentrations that refer to the study (Nurcahyono & Zubaidah, 2015) which consists of three levels, namely A1 (1%), A2 (1,5%) and A3 (2%). The second factor is Variations in chitosan concentrations refer to research (Hilma et al., 2018; Megasari & Mutia, 2019) which consists of three levels, namely B1 (1%), B2 (2%), and B3 (3%). From these two factors, 9 treatment combinations were obtained, with 2 repetitions resulting in 18 experimental experiments. Then viscosity, pH, color change, weight loss test, and organoleptic test were performed.

Formation of CMC based on Empty bunches of oil palm

The process of making carboxymethyl cellulose (CMC) from the fiber of empty oil palm bunches refers to the research of Trisnawita & Putri (2024) with modifications. The initial stage is the preparation of the oil palm empty bunches fiber, the oil palm empty bunch fibers are weighed and washed with aqueducts, then drained until there is no excess water, then dried in the oven at 60 °C for 24 hours until the moisture content decreases. The empty bunches of dried oil palm are then ground into a fine powder, then sifted using an 80 mesh sieve to obtain fractions as raw materials. The empty bunches of oil palm powder are then dried back in the oven at 60°C for 16 hours to lower the moisture content.

The next stage is cellulose insulation, in which as much as 75 g of empty oil palm bunch powder is reacted with a solution of 3.5% HNO_3 and $NaNO_2$, then heated at 90°C for 2 hours. The residue obtained is washed until neutral, then digested using a solution of 2% NaOH and 2%

Na_2SO_3 at 50°C for 1 hour. Furthermore, the bleaching process was carried out with 1.75% NaOCl at 70°C for 30 minutes, followed by purification using 17.5% NaOH at 80°C for 30 minutes and bleaching again using 10% H_2O_2.

The product is then washed and dried. The cellulose obtained is then used in the CMC manufacturing process by being suspended in water, 30% NaOH added, and heated at 60°C for 1 hour. After that, 25% trichloroacetic acid is added and heated to 50°C for 3 hours, then the mixture is filtered to obtain a residue. The residue is neutralized using acetic acid to a neutral pH, washed, soaked in methanol for 24 hours, then dried at 60°C to a constant weight and ground into CMC powder.

Manufacture and application of Edible Coating

The process of making and applying edible coating refers to the research of Hilma et al. (2018) and Nurcahyono & Zubaidah (2015) with modifications. An edible coating solution is made by dissolving CMC powder according to concentration variations (1%, 1.5%, and 2%) into 85 mL of water line that has been heated to a temperature of ±70°C, then stirred using a homogenizer until it is completely dissolved and does not clump. Next, glycerol is added as a plasticizer and stirred until homogeneous. Separately, chitosan is weighed according to the variation (1–3%), dissolved in a 1% acetic acid solution with the addition of a water line, then heated while stirring until completely dissolved. The chitosan solution is then mixed into the CMC solution gradually while stirring until homogeneous, and the pH of the solution is adjusted until it is close to neutral. The application of edible coating is carried out on the strawberries by the dyeing method for ±60 seconds, then dried and dried at room temperature (±30°C) for 15-30 minutes, then stored in cold storage before testing.

Data Analysis

The observed data included viscosity, pH, weight loss, discoloration, and organoleptic tests which were analyzed using multiple fingerprint analysis (ANOVA) at a significance level of 5% to determine the effect of treatment on the observed parameters. If the results of the analysis show a real influence, then it is followed by the Duncan Multiple Range Test (DMRT) at the level of 5%. All statistical analysis was carried out using SPSS software version 23.

RESULTS AND DISCUSSION

Viscosity Test

Viscosity is one of the important parameters in edible coating solutions because it affects the solution's ability to form a layer on the surface of food (Herdiana et al., 2023). In this study, viscosity measurements were carried out to determine the effect of variations in the concentration of chitosan and empty oil palm bunches on the viscosity level of edible coating solutions produced.

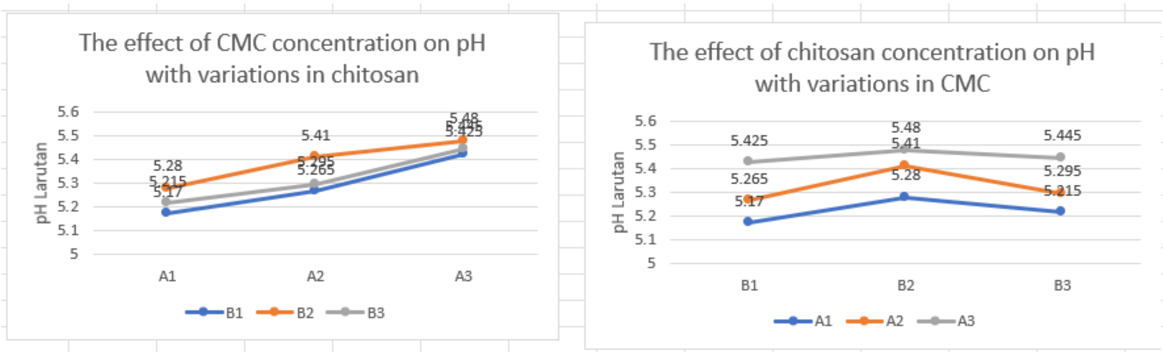

Figure 1. Effect of CMC and Chitosan Concentrations on Edible Coating Viscosity

Figure 1 shows that the increased concentration of empty oil palm and chitosan CMC based causes the viscosity of the edible coating solution to increase. The lowest viscosity value was found in the A1B1 treatment (6.05 cP) and the highest in A3B3 (47.01 cP). This trend is seen consistently, both in the increase in chitosan concentrations at each CMC level and vice versa. The results of the study showed that both factors affect the viscosity due to the increase in the amount of dissolved solids in the solution, this is in line with the research (Dewi et al., 2019) which states that the increase in viscosity is influenced by the high concentration of the material. ANOVA analysis also showed that the concentration of CMC, chitosan, and its interactions had a significant effect ($p<0.05$), which was reinforced by the Duncan test where each treatment differed significantly.

The results of this study are also supported by previous research which reported that increasing the concentration of CMC and chitosan can increase the viscosity of edible coating solutions. Abdullah et al. (2023) states that the addition of polysaccharides such as CMC is able to increase the viscosity of the solution so that it forms a more stable layer. In addition, Romanelli et al. (2021) states that an increase in the concentration of chitosan causes an increase in viscosity due to an increase in the density of molecules in the coating solution. Thus, it can be concluded that the increase in the concentration of these two substances significantly increases the viscosity of the edible coating solution.

pH Test

The pH value is one of the important parameters in the characterization of edible coating solutions because it can affect the stability of the solution as well as its interaction with the coated material. The pH measurement in this study aims to determine the effect of variations in the concentration of CMC of empty oil palm bunches and chitosan on the acidity level of the edible coating solution produced.

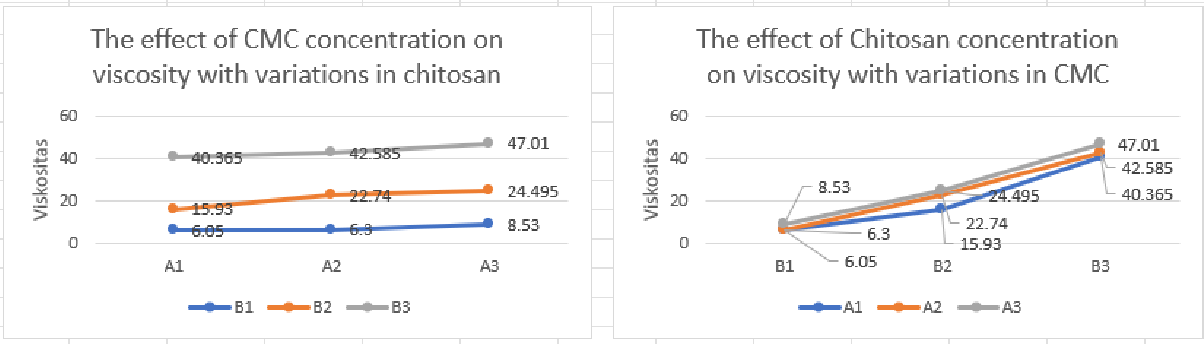

Figure 2. Effect of CMC and Chitosan Concentrations on the pH of Edible Coating

Figure 2. indicates that the pH value of edible coating solutions tends to increase with increasing concentrations of CMC of empty bunches of oil palm and chitosan, with the lowest pH at A1B1 (±5.17) and highest at A3B2 (±5.48). This increase occurs consistently with each combination of treatments, where higher concentrations of CMC result in higher pH. The ANOVA results showed that the concentration of CMC, chitosan, and their interactions had a very significant influence on pH ($p<0.05$), which was reinforced by the Duncan test showing significant differences between treatments, so it can be concluded that the variation in the concentration of the two ingredients has a significant influence on the pH value of the edible coating solution. In line with research Angelina, (2023) which states that chitosan-based coatings have good pH stability and are able to improve the quality of strawberries.

Weight Loss Test

Weight Loss is one of the important parameters in assessing the quality of fruit, as it relates to water loss during storage or after treatment. The measurement of weight loss in this study aims to determine the effect of variations in the concentration of CMC of empty bunches of oil palm and chitosan as edible coatings on the ability to inhibit weight loss in strawberries.

Table 1. Duncan Strawberry Weight Loss Double Distance Test Results

AVERAGE WEIGHT LOSS				
	B1	B2	B3	AVERAGE A
A1	29.50	30.5	30.00	30c
A2	26.82	27.725	29.50	28.01b
A3	27.27	22.695	24.59	24.85a
AVERAGE B	27.86y	26.97x	28.03y	

The results of the Duncan test in Table 1 show a marked difference between the combinations. In the CMC factor, the A3 treatment had the lowest average weight loss value of 24.85%, followed by A2 of 28.01%, and A1 of 30% as the highest value, indicating that increased CMC concentration was able to reduce weight loss. Meanwhile, the chitosan factor of B2 treatment had the lowest average value of 26.97%, while B1 and B3 had higher values and were relatively not much different, thus showing that the effect of chitosan on weight loss was not as large as the influence of CMC.

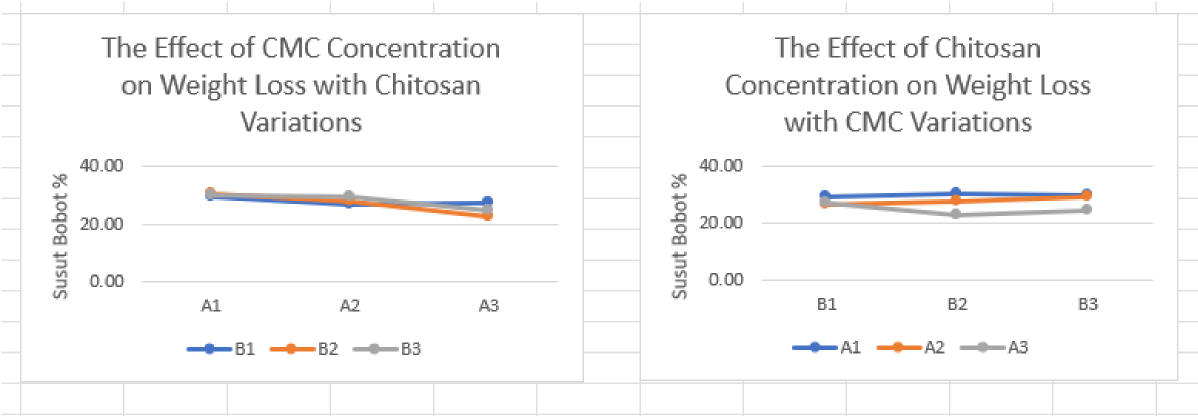

Figure 3. Effect of CMC and Chitosan Concentrations on Strawberry Weight Loss

Figure 3. showed that increasing CMC concentrations from A1 to A3 tended to reduce strawberry weight loss in each cyclic variation, so higher CMC concentrations were more effective in inhibiting water loss. Meanwhile, variations in chitosan concentrations also affect weight loss, but the effect is not as large as CMC and tends to be inconsistent. These results are in line with the ANOVA analysis and the Duncan test which showed that CMC has a more dominant influence and that there is an interaction between CMC and chitosan in influencing strawberry weight loss. In addition, these findings support the research of Trisnawita & Putri (2024) who reported that polysaccharide-based edible coatings effectively reduce water loss in strawberries during storage.

Color Change Test (chromameter)

The chromameter test is an objective color measurement method using a chromameter device that produces L*, a*, and b* values. The L* value indicates the brightness level, the a* value indicates the direction of the red to green color, and the b* value indicates the direction of the yellow to blue color. The data is then used to calculate the discoloration (ΔE), so that the degree of discoloration of an ingredient, such as strawberries, can be known due to the treatment given.

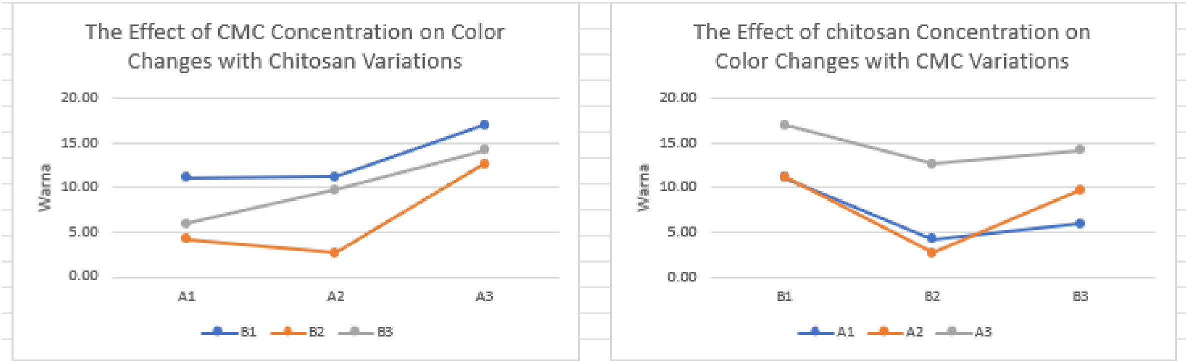

Figure 4. Effect of CMC and Chitosan Concentrations on Strawberry Fruit Discoloration

Figure 4. shows the relationship between CMC and chitosan concentrations with strawberry discoloration expressed in ΔE values. In the first graph (A), it can be seen that the increase in CMC concentration from A1 to A3 tends to increase the ΔE value at each cyclic variation, which means that the color change is even greater. This suggests that at higher concentrations of CMC, the ability to retain the color of strawberries tends to decrease. Meanwhile, in the second graph (B), it can be seen that variations in chitosan concentration also affect the value of ΔE, where the B2 treatment shows a lower value of ΔE than B1 and B3, thus showing a more stable color. Overall, these two graphs support the results of the ANOVA analysis and the Duncan test which show that CMC, chitose, and interactions both have an effect on strawberry discoloration.

The results of this study are in line with the research Bachmida *et al.* (2026) Which reports that chitosan-based edible coatings are able to maintain the color of strawberries during storage by inhibiting direct contact between fruit and oxygen. In addition, the research Kalliampakou *et al.* (2025) It shows that biopolymer-based edible coatings can slow down fruit discoloration by reducing the rate of respiration and pigment oxidation during storage. Thus, the combination of CMC based on empty oil palm bunches and chitosan in this study showed the potential in maintaining the visual quality of strawberries during storage.

Hedonic Organoleptic Test

The hedonic organoleptic test is an assessment method carried out by panelists to determine the level of likability of a product using a like to dislike scale. In the edible layer stoberry study, this test is used to assess panelists' acceptance of changes in color, aroma, texture, and taste.

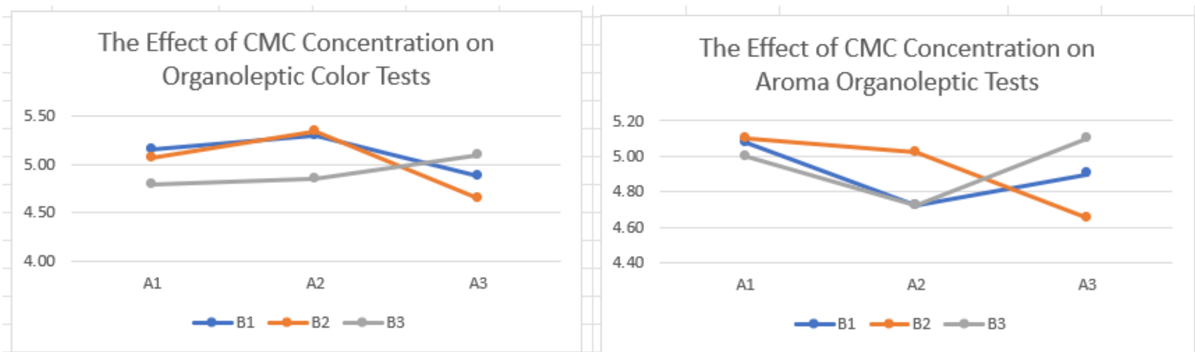

Figure 5. Effect of CMC Concentration with Chitosan Variation on Color and Aroma Organoleptic Test

The graph in Figure 5 shows that the concentration of CMC with chitosan variation affects the organoleptic value of the color and aroma of the strawberries. In the color test (left graph), the increase in CMC concentration from A1 to A2 tends to increase the color value, especially in the B1 and B2 treatments, but in A3 the color value actually decreases in some treatments. The highest color value is generally in the A2 combination, while in B3 the trend is relatively stable and slightly increased. This suggests that a particular concentration of CMC (A2) provides the color display most favored by the panelists, but further improvements do not necessarily improve color quality. In the scent test (right graph), the pattern displayed is most likely inconsistent. The scent value decreased from A1 to A2 in almost all treatments, then increased again in A3 for some combinations (especially B3), while in B2 it continued to decrease. This suggests that the concentration of CMC and chitosan does not exert a strong and consistent influence on the scent.

The results of this study are supported by research Mufidah et al. (2022) Which reports that edible coatings based on polysaccharides and chitosan are able to maintain the visual quality of the fruit without causing significant sensory changes in aroma. Overall, these results suggest that treatments have a greater effect on color attributes than scents, where colors tend to undergo changes that are more pronounced than scents.

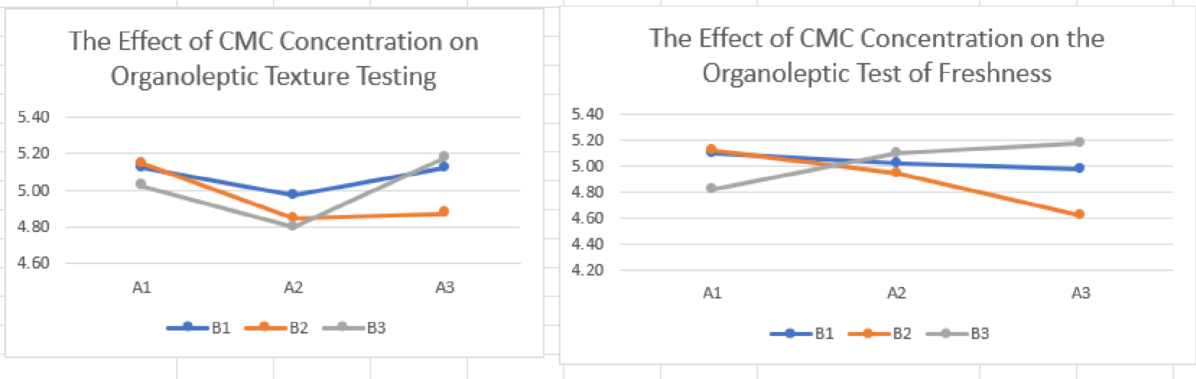

Figure 6. Effect of CMC Concentration with Chiosan Variation on Texture and Freshness Organoleptic Test

The graph in Figure 6 shows that the concentration of CMC with chitosan variation affects the organoleptic value of the texture and freshness of the strawberries. In the texture test, the value on A1 was relatively high in the range of 5.03–5.15, then decreased on A2 to 4.80–4.98, and again increased on A3 in the range of 4.88–5.18. The highest score was found in the combination of A3B3 (5.18), while the lowest was found in A2B3 (4.80). The average showed that A1 (5.10) and A3 (5.06) did not differ significantly, but were higher than A2 (4.88). Based on the kitasan factor, B1 had the highest average (5.08), followed by B3 (5.00) and B2 (4.96), suggesting that higher concentrations of CMC were able to improve texture after a decrease in intermediate concentrations.

In the freshness test, the values ranged from 4.63–5.18, with the highest in A3B3 (5.18) and lowest in A3B2 (4.63). In B1, the value is relatively stable (5.10; 5.03; 4.98), in B2 it tends to decrease (5.13; 4.95; 4.63), while in B3 it increases (4.83; 5.10; 5.18). Average A shows relatively similar values (A1 = 5.02; A2 = 5.03; A3 = 4.93) and no real difference, as well as a B average (5.03; 4.90; 5.03). This shows that freshness is more influenced by the interaction between CMC and chitosan, where the combination of high concentrations (A3B3) gives the best results in maintaining the freshness of strawberries.

Based on the results of this study, in line with Paramita et al. (2026) Yang reports that chitosan-based edible coatings are able to maintain the texture and freshness of strawberries during storage by reducing moisture loss and slowing down the softening of fruit tissues.

CONCLUSION

Based on the results of the study, it can be concluded that variations in the concentration of CMC of empty oil palm bunches and chitosan affect the characteristics of the peedible coating and the quality of strawberries. The increased concentration of the two ingredients is able to increase the viscosity of the solution, as well as exert an influence on the organoleptic parameters, where the color and texture are noticeably affected, while the aroma does not show a significant influence and freshness is affected by the interaction of the two. In addition, the edible coating produced is able to suppress weight loss so that it helps maintain the quality of strawberries during storage. This shows that there is an interaction between the CMC of empty oil palm bunches and chitosan in improving the performance of edible coatings. Overall, the combination of CMC of empty oil palm bunches and chitosan has the potential to be used as an effective edible coating in maintaining the quality and extending the shelf life of strawberries.

Thus, this study shows that the use of empty oil palm bunch waste as a source of CMC can be an alternative to value-added biopolymer raw materials and has the potential to be developed in the post-harvest application of fresh fruit. In addition, the use of edible coatings based on CMC and chitosan is expected to support the development of food packaging technology that is more environmentally friendly and sustainable. Further research is recommended to conduct further testing of the film's mechanical properties, Water Vapor Transmission Rate (WVTR), antimicrobial activity, and the effectiveness of edible coatings on other types of fruit and longer storage periods.

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