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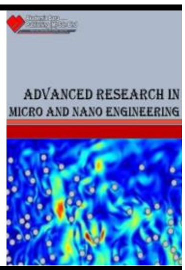

Influence of Hydrocolloids as Coating on Physicochemical Properties of *Averrhoa Carambola L.*

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ABSTRACT

Averrhoa carambola also known as starfruit is a common fruit in tropical and a rich source of minerals and vitamins. Starfruit contains high water content and easily rots thus affecting its physicochemical characteristic and diminishing its quality if stored at normal temperature. To overcome this issue, hydrocolloids can be used as a coating that acts as a protective barrier in minimizing transpiration and respiration in addition to improving the quality characteristics of starfruit. In this study, three different types of hydrocolloids namely carboxymethyl cellulose (CMC), xanthan and guar gums were used in producing coating solutions. The aim of this study is to determine the influence of hydrocolloids coating in response to the physicochemical properties of starfruit. In this study, the coating solutions that contained CMC-guar gum (CMC:GG) and CMC-xanthan gum (CMC:XG) at concentrations of 0.5% and 1.5% were prepared. All hydrocolloids were mixed and heated at 60ºC for 40 minutes with the addition of 3% glycerol. Starfruits were dipped into solutions coating for 2 minutes, air dried and stored for 12 days at 20ºC. Weight loss, firmness, color differences, pH of starfruit, moisture content, total soluble solids, sugar concentration, ascorbic acid and total phenolic content were analyzed during 12 days of storage. Results from this study demonstrated that the combination of 1.5%CMC:1.5%GG exhibited better results in terms of weight loss with 30.67%, pH of 3.67, moisture content of 91.16%, firmness with 2017.61 N and the lowest value of total color difference. On the other hand, a similar combination exhibited an ascorbic acid content of 16.71 mg/ 100 ml and a total phenolic content of 0.0089 mg GAE of fresh sample. As a conclusion, a coating made from different combinations of hydrocolloids can be an alternative protective barrier for starfruit as it could improve the physicochemical properties as well as preserve the freshness of fruits.

1. Introduction

Starfruit *(Averrhoa carambola L.)* is mainly sold as fresh fruit and is rich in magnesium, potassium as well as containing natural antioxidants, ascorbic acids and carotenoids. Starfruit is easily spoilt due to high levels of moisture thus causing higher postharvest losses as reported by Gol *et al.,* [1].

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Mohamad Zaki *et al.,* [2] stated that starfruit that is ripe has thin skin and is easily infected by microorganisms and engulfed with mold within a few days of normal storage.

Kim *et al.,* [3] mentioned that edible coating is defined as a thin layer coating on the surface of food to provide physical protection while selectively blocking the permeation of gas, water vapor and solvents. The edible coating could improve the appearance of the fruit by giving a glossy surface and preventing the colour change of the product. Besides natural wax coatings, there are wide range of materials that can be used as edible coatings and films such as lipids, polysaccharides, carbohydrates, and proteins as reported by several authors such as [4,5]. Edible coatings are now considered as the new approach for fruit and vegetable preservation. It can be directly applied on the surface of the fruits or vegetables as an additional protection. Maftoonazad *et al.,* [6] and Mannozzi *et al.,* [7] in their studies reported that edible coatings based on polysaccharides materials such as mixtures of carboxymethyl cellulose could delay ripening and decaying besides minimizing moisture loss, respiration as well as maintaining fruit firmness. A study by Menezes and Athmaselvi [8] demonstrated that carbohydrate-based coating can extend the shelf life of the fruit up to 11 days by delaying the changes in weight loss, total soluble solids, pH, total acidity, firmness and color.

Carboxymethyl cellulose (CMC) is one example of hydrocolloid that is being used as an edible coating and has dominated in food industry. It is a polysaccharide-based substance characterized as a linear, long chain with high solubility and mechanical properties that allow it to be used as a fruit coating as mentioned by Hassan *et al.,* [9]. It has been used as a coating material by several researchers such as Tesfay and Magwaza [10] in extending the shelf life of peaches, pears and avocados.

Guar gum is extracted from the endosperm of guar (*Cyamopsis tetragonoloba*) seeds and consists of high molecular weight polysaccharides with linear backbone chain of β-1, 4-linked mannose units to α-1, 6-linked galactose groups. The ratio of mannose to galactose units is 2:1 as reported by Saberi *et al.,* [11]. Previous studies on guar gum-based coating have been reported by several authors [11-13] on orange, cherry and mango to maintain fruit quality. In another study by Ruelas-Chacon *et al.,* [14], guar gum is also used as an edible coating in Roma tomato and the surface coated exhibits a transparent appearance and shrank less compared to the untreated one.

Xanthan gum is an extracellular polysaccharide that is produced by *Xanthomonas campestris*. It provides texture, viscosity, release of flavour, appearance and water regulating properties to food. The effect of xanthan gum as a coating has been studied on minimally processed pear by Mohamed *et al.,* [15], fresh cut apples by Zambrano-Zaragoza *et al.,* [16] and on fresh cut pears as reported by Sharma and Ramana Roa, [17]. There is limited research into the physicochemical properties that might change over prolonged storage after the CMC-xanthan gum or CMC-guar gum is applied as an edible coating on starfruit. Therefore, this study aimed to investigate the efficacy of hydrophilic polysaccharide based edible coating CMC combined with other hydrocolloids in improving the quality of starfruits as well as to develop an edible coating that could extend the shelf life of starfruit.

2. Methodology

2.1 Materials

Starfruits *(Averrhoa carambola L.)* that is similar in size and dimensions and half mature with vibrant green in colour was bought from Pasar Klang, Selangor. It was washed with water and air-dried using a paper towel prior to use. Chemicals used in these studies were glucose, fructose, sucrose, acetonitrile, ascorbic acid, sodium hydroxide, carboxymethyl cellulose, guar gum, xanthan gum, sodium bicarbonate, Follin-Ciocalateu reagent, Gallic acid, acetic acid, 2,6-dichlorophenolindophenol, meta-phosphoric acid and glycerol. All chemicals were obtained from Next Gene Scientific Sdn. Bhd.

2.2 Preparation of Edible Coating Solutions and Coating Process

0.5 g of CMC was added to 100 ml of distilled water to make a concentration of 0.5%. A similar procedure was applied to prepare 0.5% xanthan gum (0.5%XG) and 0.5% guar gum (0.5%GG) coating solutions. Coating solutions with a concentration of 1.5% were prepared for all hydrocolloids. Once the coating was ready, 0.5% of CMC was mixed with 0.5% xanthan gum for 40 minutes at 60°C. Then, 3% of glycerol was added to the coating mixture. The coating mixture was stirred for another 30 minutes at the same temperature. This coating was known as 0.5%CMC:0.5%XG and it was kept in a container and stored at room temperature. A similar procedure was used to prepare 0.5%CMC:0.5%GG, 1.5%CMC:0.5%XG, 1.5%CMC:1.5%GG. Finally, starfruit was dipped in the coating solution for 2 minutes and all samples were air dried for 2 hours before stored at a temperature of 20°C for 12 days. Figure 1 shows the coating process of starfruits.

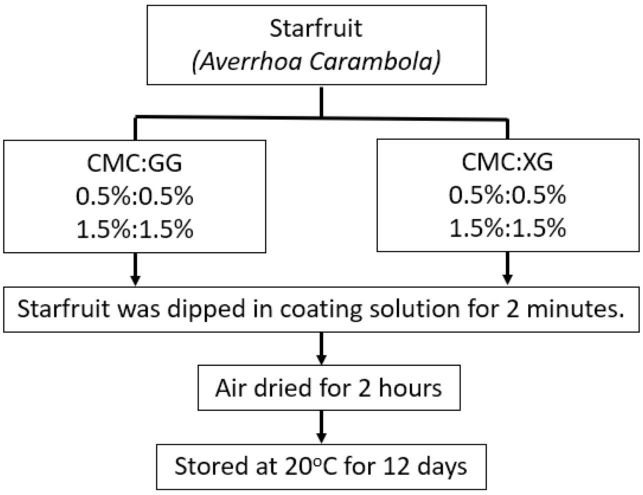

Fig. 1. Coating process of starfruits

2.3 Evaluation of Physicochemical Properties
2.3.1 Weight loss and firmness

Weight loss was determined by adopting the following formula

$$\text{Weight loss} = \frac{(\text{Weight of fruit on day 0} - \text{weight of fruit on sampling day}}{\text{weight of fruit on day 0}} \text{ x } 100 \quad (1)$$

The firmness of starfruit was measured using a Texture Analyser instrument (TA-XT2i plus, Stable Micro Systems, UK) using a 5 mm diameter stainless steel cylinder probe (P/0.5mm). The force during compression was measured using the load cell of 5 kg capacity with a test speed of 1mm/s. Firmness was measured as the maximum force recorded in a force-time curve obtained from a Texture Analyser during the compression of starfruit by cylinder probe.

2.3.2 Total colour difference

For the total color difference, a chroma meter was used to identify the L, a and b values. L, a, b values refer to lightness, redness-greenness and yellowness and blueness. Prior to use, the Chroma meter (CR-400, Konica Minolta, Japan) was calibrated with a standard white plate. Starfruit was placed over the Chroma meter and measurements were recorded at three different points of each sample.

2.3.3 Total soluble solids and titratable acidity

The starfruit was blended in a juice extractor and the slurry was filtered through cheese cloth to separate its pulps. The juice was used to estimate total soluble solids, titratable acidity, and ascorbic acids. The measurement of total soluble solids was carried out by placing a few drops of juice on a hand refractometer. For titratable acidity determination, 10 ml of juice was diluted with 250 ml in a conical flask. 2 to 3 drops of phenolphthalein were added into the conical flask as an indicator. The mixture was titrated with 0.1 M NaOH. The titratable acidity of starfruit was calculated by using the equation below:

$$\text{Titratable acidity }(\%) = \frac{\text{0.1 M NaOH x Volume of NaOH x 0.045}}{\text{Volume of sample}} \quad (2)$$

2.3.4 pH and moisture content

One piece of starfruit from each treatment was blended using a juice extractor. Then, the starfruit slurry was filtered using cheesecloth to separate its pulp and juice. The juice was collected and used to measure the pH using a pH meter.

For moisture content, 5 g of starfruit was cut, and its initial weight was recorded. Then, the sample was dried in an oven at 105^{o}C for 12 hours. The final weight of the sample was recorded, and moisture content was calculated using the following equation:

$$\text{Moisture content} = \frac{\text{(Initial weight of sample – Final weight of sample)}}{\text{Initial weight of sample}} \text{ x } 100 \quad (3)$$

2.3.5 Ascorbic acid

Ascorbic acid was determined using the AOAC [18] method. About 5 mL of metaphosphoric acid-acetic acid solution and 2 mL of starfruit juice were pipetted into a 50 mL Erlenmeyer flask. Each sample was titrated with the indophenol dye solution until a light but distinct rose-pink colour persisted for more than 5 seconds. The amount of dye used for each titration was recorded and the amount of ascorbic acid was calculated.

2.3.6 Sugar and total phenolic content

A stock solution of 10% of each sugar (fructose, glucose and sucrose) was prepared by dissolving 1 g of each sugar into a 10 ml volumetric flask with mobile phase (Acetonitrile: Deionized water=75:25) the volume will be marked up to 10 ml. A series of standard solutions 0.5%, 1.0%, 1.5% and 2.0% were prepared by diluting the sugar stock solution using deionized water in a 10 ml volumetric flask. A small amount of the series standard solution was passed through a membrane filter (0.45 µm) into a glass vial. The blank and standard solution was analysed by injecting 10 µl into High performance liquid chromatography-evaporative light scattering detection (HPLC-ELSD) system. A similar procedure was used to analyse samples with 1 ml of the juice pipetted into a 10 ml volumetric flask.

For total phenolic content, it was determined using a modified version by Castro-Concha *et al.,* [19]. 200 µL of juice was mixed with 1.5 mL Folin-Ciocalteus's reagent. Then, 1.5 mL of 0.556 M sodium bicarbonate was added and mixed. After that, the absorbance was measured at 760 nm and total phenolic content was assessed using the gallic acid calibration curve. It was expressed as milligrams of Gallic acid of fresh sample.

2.4 Statistical Analysis

All measurements were composed of triplicate and the mean of data was analysed using SPSS version 26 as well as to determine the significance difference of mean between different concentrations.

3. Results and discussion

3.1 Effect of Coatings on Physicochemical Properties of Averrhoa Carambola

3.1.1 Weight loss and firmness

Edible coatings act as a barrier property in reducing the transpiration and respiration rate of the fruits that occurred during post-harvest handling and storage thus enhancing its quality and shelf life. In this study, a combination of CMC with guar gum and xanthan gum reduced the weight loss of the fruits. According to Aloui and Sanchez [20], the weight loss of fruits is due to the increase in water loss resulting from the transpiration and respiration of the fruits. The main mechanism of weight loss is contributed by the evaporation of water activated by a gradient water vapour pressure at different parts of the fruits as reported by Yaman and Bayoundurlu, [21]. In this study, weight loss of starfruit increased in all treated samples during days 4, 8 and 12 of storage. However, all treated samples showed weight loss of below 38%. Compared to untreated starfruit the highest weight loss was recorded at day 12 with 45.33%. Amongst all samples, 1.5%CMC:1.5%XG demonstrated the lowest reduction in weight loss.

From the findings, the firmness of starfruit decreased during the 12 days of storage period. As it approached day 12, uncoated starfruit exhibited the lowest firmness compared to coated starfruits with 799.08 N, followed by 0.5%CMC:0.5%XG with 997.05±5.68 N. 1.5% while 1.5%CMC:1.5%GG demonstrated the highest firmness of 2017.63±25.16 N compared to another sample. Edible coating acts as a gas barrier which slows down the outward loss of carbon dioxide and inward movement of oxygen, while still allowing for respiration. Yaman and Bayoundurlu, [21] stated that low oxygen and high carbon dioxide concentrations reduce the activity of enzymes and allow retention of firmness of fruits during storage. The coating could retard the activities of pectin-degrading enzymes where it causes fruit softening by reducing the rate of metabolic processes during senescence as studied by Zhou *et, al.,* [22] which contributes to the firmness of fruits. The firmness of the fruits decreases due to the breakdown of the cell wall and loss of turgor pressure due to moisture loss during storage demonstrated by Mohammad Zaki *et al.,* [2].

3.1.2 Total colour difference

The respiration rate causes color changes of the skin and flesh of fruits thus indicating increases in maturity. Mohammad Zaki *et al.,* [2] mentioned that the green colour of Carambola is due to the presence of chlorophylls, but as chlorophylls degrade and enzymatic reactions occur, anthocyanins and carotenoids pigments were produced providing the colour red and orange respectively. As of day 4, the total colour differences of coated and uncoated starfruit showed no significant differences (p>0.05). However, as it approached day 12, the total colour difference of uncoated starfruit is higher compared to day 0 with a value of 691.31. Starfruit coated with 1.5%CMC:1.5%GG demonstrated the lowest value compared to other coated samples with 487.25. 0.5%CMC:0.5%GG recorded the value of 510.10 while 0.5%CMC:0.5%XG and 1.5%CMC:1.5%XG exhibited the values of 557.08 and 551.04 respectively. Maaftoonazad *et al.,* [23] in his study reported that edible coating could slow down the respiration rate, reduce the color changes of skin and flesh and increase the shelf life of fruits.

3.1.3 Total soluble solids and titratable acidity

Total soluble solid (TSS) is the measurement of sugar content in sugar solutions which is determined by the index of refraction referred to as degree Brix (°Brix). Comabella and Lara, [24] in their study exhibited that an increase of TSS during storage in fruits occurs because of water loss, hydrolytic enzyme activities, a decrease in respiration rate and conversion of sugars in CO_2 and H_2O. In this study, there is an increase in TSS of coated and uncoated starfruit. Uncoated starfruit showed the highest TSS on day 12 with 9.80°Brix. The values for total soluble solids of all samples were between 5.70°Brix to 9.80°Brix during 12 days of storage. Among coated samples, the lowest TSS was demonstrated by 1.5%CMC:1.5%GG with 8.26°Brix at day 12.

Titratable acidity measures the content of organic acid in the fruit as over the period, the titratable acidity decreases due to organic acids being used as a substrate for enzyme catalysed reactions during aerobic respiration in plant cells. Due to this reaction, a reduction of acidity will occur thus giving fruit a sweet taste since organic acids converted it into sugar as in Mattoohazad *et al.,* [25] study. Babu *et al.,* [26] described that oxalic acid is the main organic acid presence in Carambola which contributes to its sour taste and low pH value. In this study, there is a decrease in the amount of titratable acidity in coated and uncoated starfruit. Towards day 12, coated and uncoated starfruit experienced a decrease in acidity. The lowest acidity was observed in 0.5%CMC:0.5%XG with 0.13% while for uncoated starfruit the value of acidity left was 0.17%. The highest value of acidity presence in fruits was exhibited by 0.5%CMC:0.5%GG with 0.21%. Previous study by Panahirad *et al.,* [5]. showed that plum coated with CMC and pectin can reduce the rate of loss of acidity thus enhancing the plum shelf life and reducing the rate of ripening stage.

3.1.4 pH and moisture content

The pH of Carambola is largely influenced by the presence of oxalic acid. As storage days increase, the pH also increases in both coated and uncoated starfruits. pH increases as fruit matures during storage due to the breakdown of acids in the respiration process which is influenced by oxygen uptake and releases of carbon dioxide. From this study, uncoated starfruit contained a pH of 3.92 while 1.5%CMC:1.5%GG recorded the lowest pH with 3.67 at day 12. During 12 days of storage, there was a reduction of moisture content in coated and uncoated samples. Amongst all coated samples, starfruit coated with 1.5%CMC:1.5%GG could retain its moisture content at 91.16%. The reduction in moisture content is parallel to the reduction of weight loss in all samples. The moisture content of fruits is important because it affects the freshness of fruits.

3.1.5 Ascorbic acid

Al-Sanafi, [27] in his review explained that ascorbic acid is a potent free radical scavenger which prevents the degradation of fruits during the ripening process. During storage, ascorbic acid content decreases due to degradation when exposed to light thus it degrades by oxidation. In this study, ascorbic acid decreased slightly during storage of 12 days. For uncoated starfruit and starfruit coated with 0.5%CMC:0.5%GG, the values of ascorbic acid were 11.07g/100ml and 10.85g/100ml respectively. Starfruit coated with 1.5%CMC:1.5%GG and 1.5%CMC:1.5%XG demonstrated the highest ascorbic acid content on day 12 16.71g/100ml and 15.63g/100mlrespectively. This shows that the coating material of guar and xanthan gums incorporated with CMC lowered the oxygen permeability and the activity of enzymes resulting in the prevention of the oxidative deterioration of ascorbic acid.

3.1.6 Sugar concentration and total phenolic content

Fructose, glucose and sucrose concentrations in starfruits increase over the storage period. From the results, uncoated starfruit showed the highest fructose and glucose concentrations with 0.97% and 1.41% respectively on day 12. The lowest fructose and glucose concentrations were starfruit treated with 1.5%CMC:1.5%GG with values of 0.48% and 0.66% respectively. On the other hand, starfruit coated with 0.5%CMC:0.5%GG exhibited lower values with 0.90% and 1.30% for fructose and glucose concentrations. Meanwhile, all samples showed a similar amount of sucrose concentration as the fruits ripen might be due to starch that has breakdown into sucrose earlier before it breaks down much more into glucose and fructose. Coating the fruits with edible coating can reduce the respiration rate of the fruits which leads to enzymatic reaction thus reducing the rate of sugar synthesis.

From this study, a slight reduction of total phenolic content occurs on day 4 and day 8. As it approaches day 12, a significant decrease can be seen for all coated and uncoated starfruit ($p<0.05$). All coated samples demonstrated TPC that ranged between 0.010 to 0.014mg GAE of fresh sample. Phenolic compounds are secondary metabolites that are presence in edible tissues in plants such as fruits, leaves, stems and roots. They are produced through the phenylpropanoid metabolization process as reported by Zam [28].

4. Conclusions

According to the studies, edible coating developed using carboxymethyl cellulose, xanthan gum and guar gum at different concentrations can reduce weight loss and enhance the firmness and other chemical properties of starfruit. The combination of different hydrocolloids could also extend the shelf life of starfruit delaying the respiration rate of the fruits. Amongst all samples, starfruit coated with 1.5%CMC:1.5%GG exhibited the best result in terms of weight loss with 30.67%, pH of 3.67, moisture content and firmness of 91.16% and 2017.61 N respectively. The combination of CMC and guar gum also improves the total colour difference with 180.79, ascorbic acid content of 16.71 mg/ 100 ml and total phenolic content of 0.0089 mg GAE of fresh sample. Therefore, edible coating developed using these types of hydrocolloids can be a new alternative to edible coating to maintain the quality of fruits.

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