Characterisation of polysaccharide composite incorporated with turmeric oil for application on fresh-cut apples

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Abstract. Composite edible coatings were made up from two types of polysaccharide which are cassava starch and carboxymethyl cellulose (CMC) incorporated with turmeric oil (TO) as an antioxidation agent. Weight loss, firmness loss and moisture content were studied to determine the effect of composite edible coating incorporated with different TO concentration and dipping times towards the quality of fresh-cut Fuji apples. Findings showed that the coating with 17.5 μL/mL concentration of TO and 180 s dipping time had the lowest weight loss and percentage of firmness loss. While for percentage of moisture content, 17.5 μL/mL concentration of TO with 60 s dipping time had the lowest moisture content loss. Surface morphology was analysed to observe the uniformity of coating on fresh-cut Fuji apples surface. The oxidase enzyme activities of fresh-cut Fuji apples reduce when there is TO present in edible coating. It showed that the coating with 180 s dipping time had the best surface coating compared to 60 s and 300 s dipping time. The composite edible coating emulsion can be huge potential as fresh-cut fruits coating to preserve the quality of the fruits.

1. Introduction

Fresh-cut fruits are ordinarily characterised as fruits that have been subjected to various handling procedures to acquire a complete edible product while giving convenience and usefulness to the consumers and guaranteeing food safety [1]. The advertising of fresh-cut fruits is constrained by a short time span of usability and quick deterioration of their segments because of tissue harm as an aftereffect of handling, e.g. washing or cutting, and the microbial development [2]. The most critical problem that commonly faced by fresh-cut fruits is the enzymatic browning. Enzymatic browning process could lead to reduce in weight, firmness and moisture content [3]. Fruits that contain high sugar usually confront enzymatic browning problem [4].

Edible coating method have been broadly considered to preserve the organoleptic properties of fruits and vegetables. Hydrocolloid substances that has edible properties such as protein, polysaccharides and lipids will be enforced on the surface of the product in the form of thin layer [5]. Composite edible coatings are made up from the mixture of these hydrocolloids which to diminish the disadvantages of a single hydrocolloid substance and produce stable edible coating [6]. Composite edible coatings are able to incorporate with additives such as antioxidation agent, antimicrobial agent and colouring agent in order to enhance the properties of edible coating and prolong the fruits shelf life [7, 8]. For example, the antioxidation agent can be added into the composite edible coating emulsion to delay the enzymatic browning process and retain the weight, firmness and moisture content. Nowadays consumers are more aware and concern on the use of antioxidation agent from natural sources and being ‘recognized as safe
as safe for consumer and environment, such as essential oil. Essential oil contains various types of compounds that can act as antioxidation agent eg. monoterpene, sesquiterpenes and prophenylphenol [9]. Turmeric essential oil extracted from its rhizomes is one of the antioxidation agent that has higher amount of active compounds such as turmerone, curcuminoinds, and Ar-turmerone, compared to other parts [10].

Therefore, the aims of this research are i) to determine the effect of composite edible coating incorporated with different concentration turmeric oil and different dipping time towards fresh-cut Fuji apples through characterisation studies of weight loss, percentage of firmness loss, percentage of moisture content and oxidase enzyme activities, and ii) to analyse the surface morphology of composite edible coating on the surface of fresh-cut Fuji apples.

2. Materials and Methodology

2.1. Materials

Fresh Fuji apples were purchased from local market and used as the samples for this study. The samples used have constant shape, same size, without any defects and were partially ripe. Apple cutter was used to cut the fresh Fuji apples into wedges shape so that it has similar size of apple wedges. Cassava flour (Cap Kapal ABC Co, Malaysia) and carboxymethyl cellulose (CMC) (Novelecell, Malaysia) were used as the edible composite materials. Citric acid (Merck, United States) was used as the cross-linking agent, while glycerol (Merck, United States) was used as plasticizer and extracted turmeric oil (TO) was used as the antioxidation agent.

2.2. Edible coating preparation

An amount of 6 g of cassava starch was diluted in 100 mL of distilled water for 40 min at temperature 80 °C. Then, 0.5 g of 0.5 M citric acid was added in the emulsion and followed by 2 mL of glycerol. Next, 2 g of CMC was solubilized in 100 mL of distilled water for 30 min at 75 °C. Lastly, different concentration of TO (5, 17.5 and 30 μL/mL) was added into each of the emulsion and then the fresh cut apples were dipped into the formulation for different dipping time (60, 180 and 300 s) by using dip coater machine. The samples were dried and then stored in the chiller at temperature of 6 °C.

2.3 Weight loss

Weight loss analysis was done according to Soares et. al. [11] with few alterations. The fresh-cut Fuji apples were weighed on the digital balance and the total weight loss was calculated by using Equation (1), where $W_i$ is the initial weight of the fresh-cut Fuji apples and $W_f$ was the final weight of the fresh-cut Fuji apples. The weight reading was taken triplicate. The samples were weighed before and after 5 days which is the common maximum storage period applied by consumer for fresh-cut apples.

$$\text{Weight Loss} = W_i - W_f \quad (1)$$

2.4 Firmness loss

The firmness test was done by following Liu et. al. [12] with slight modification. The firmness of the fresh-cut apples was determined by using the hand-held compact penetrometer (Agriculture Solution (Model: FHP-802)) with tip size of 3.5 mm. The average firmness reading of fresh-cut Fuji apples was recorded and the percentage of firmness loss was calculated using Equation (2). The $F_i$ was the initial firmness and $F_f$ was the final firmness.

$$\text{Firmness Loss} = \frac{F_i - F_f}{F_i} \times 100 \quad (2)$$

2.5 Moisture Content

The percentage of moisture content loss was ascertained by using AOAC method 920.151 [13, 14]. The fresh-cut Fuji apples were placed in aluminium canister and dried in the oven for 10 hours at 60 °C. The
weight of aluminium canister, fresh-cut ‘Fuji’ apples before and after drying were recorded. The percentage moisture content loss was calculated using Equation (3), where MCi is the moisture content of wet sample (g) and MCf is the moisture content of dry sample (g).

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\text{Moisture Loss} = \frac{MC_i - MC_f}{MC_i} \times 100
\]  

(3)

2.6 Oxidase enzyme assay

The oxidase enzyme was determined according to Thipnate et. al. [14] procedures with few modification. The coated and uncoated fresh-cut ‘Fuji’ apples were homogenised with 50 mL of 0.1 M sodium phosphate buffer (contained 10 g/L polyvinylpyrrolidone and 5.0 g/L Triton X-100) with pH 6.8 and temperature of 4 °C by using laboratory blender 7011HS (Waring, USA). The fresh-cut Fuji apple juice or known as crude was collected. The reaction mixture of catechol solution and enzyme in crude was formulated in 0.05 M sodium phosphate buffer at pH 6.8. The absorbance reading was measured with UV-Vis spectroscopy at 420 nm in room temperature. The blank used was the substrate solution.

2.7 Surface morphology of coating

The uniformity of coating was observed by using Scanning Electron Microscope (SEM). This analysis was done according to Ruzainah et. al. [15] methodology with few modification. The coated fresh-cut Fuji apples were cut into rectangle pieces with measurement of 6 mm x 3 mm and 1 mm thickness. The product was coated with platinum coating in vacuum condition before being observed. The surface morphology was analysed by using accelerating voltage of 1.5 kV and 100x of magnification. The percentage surface area without cracks and hole were calculated by using grid paper.

3. Results and Discussion

3.1 Weight loss

Figure 1 shows that the uncoated fresh-cut Fuji apples had the highest total weight loss compared to the coated fresh-cut Fuji apples. The coated samples had reduced weight loss due to the presence of hydrophobic compounds in the starch-based composite edible coating. Thus, it can diminish the fresh-cut Fuji apples weight loss. This finding was supported by Hirashima et. al. [16]. From Figure 1, it can be observed that samples coated with no incorporation of turmeric oil suffered the highest weight loss for all dipping time. This indicated that the addition of turmeric oil in the starch-based composite edible coating had the ability in reducing the weight loss of the fresh-cut Fuji apples. Besides that, it shows that samples coated with 17.5 μL/mL of TO at 180 s dipping time had the lowest total weight loss with value 0.898 g compared to all coated fresh-cut Fuji apples. The 60 s dipping time for all turmeric oil concentration had higher weight loss than 180 s. The same trend was obtained for 300 s dipping time. This indicated that shorter dipping time of the fresh-cut apples in formulation was not capable to retain the weight loss as it was unable to control the respiration rate. While, longer dipping time increased the coating thickness, thus, anaerobic condition took place in the fresh-cut Fuji apples. The similar trend was observed by Bartz and Brecht [17] for fresh maize on the cob. It can be concluded that 180 s is the maximum dipping time for this research study because it was able to produce the desired thickness that can retain the quality of fresh-cut Fuji apples.
3.2 Percentage of firmness loss

Figure 2 shows the percentage of firmness loss of fresh-cut Fuji apples after 5 days. The firmness loss had similar trend as the weight loss analysis. It was observed that the uncoated fresh-cut Fuji apples have the highest percentage of firmness loss among others which is 38.33%. On the other hand, the percentage of firmness loss for the coated fresh-cut Fuji apples was lower with the presence of turmeric oil. According to Amin [18], the essential oils have positive effect in firmness of fruits. It can be seen from Figure 2 that apples coated with 17.5 μL/mL concentration of TO with dipping time of 180 s shows the lowest percentage of firmness loss with 18.38% compared to other concentration of turmeric oil. The percentage of firmness loss was proportional to the total weight loss for fresh-cut Fuji apples as discussed earlier. It can be concluded that coating with 17.5 μL/mL of TO and 180 s dipping time provided the best coating quality compared to others.

Figure 1. Total weight loss of fresh-cut Fuji apples after 5 days.

Figure 2. Percentage firmness loss of fresh-cut Fuji apples after 5 days.
3.3 Percentage of moisture loss
The percentage of moisture loss of coated apples with TO (5, 17.5 and 30 μL/mL) and uncoated fresh-cut apples was measured using laboratory digital balance. The coated apples were dipped in the edible coating emulsion for 60, 180 and 300 s dipping time. Figure 3 shows the percentage of moisture loss on the last day of storage (Day 5). It can be seen that control sample (uncoated apples) had the highest moisture loss which is 92.21% after 5 days of storage compared to all coated fresh-cut Fuji apples. This finding was in agreement with Sipahi [19] which reported that the moisture content of control sample significantly decreased during storage time. Furthermore, it can be observed that between all TO concentrations used, coated apples with 17.5 μL/mL TO had the lowest percentage of moisture loss. Furthermore, between all coated apples, the lowest moisture loss was found in sample with 60 s dipping time and 17.5 μL/mL TO which is 82.61% and the highest moisture loss was 60 s dipping time with 5 μL/mL TO which is 86.43%. This shows that the addition of turmeric oil in the edible coating emulsion reduced the moisture loss in the fresh-cut Fuji apples. This might be due to the lipid hydrophobic behaviour of the coating emulsion which is effective as moisture barrier, thus moisture can be retained in the coated fresh-cut apples.

![Figure 3. Percentage moisture loss of fresh-cut Fuji apples after 5 days.](image)

3.4 Oxidase enzyme activities
The analysis for oxidase enzyme activities was done for fresh-cut Fuji apple samples which were the control (uncoated), 0 μL/mL and 17.5 μL/mL of TO coated with composite edible coating emulsion (CECE) with 180 s dipping time. Figure 4 shows the oxidase enzyme activities for 1, 3 and 5 days of storage. The uncoated sample (control) had the highest oxidase activities which is 0.890 ± 0.002 followed by CECE without incorporation of TO which is 0.589 ± 0.009 and lastly CECE incorporated with 17.5 μL/mL of TO which is 0.496 ± 0.028. The presence of TO in edible coating improved the fresh-cut Fuji apples condition and delayed the enzymatic browning process on its surface. The oxidase enzyme activities for fresh-cut Fuji apples coated with CECE without TO were lower than the uncoated samples. Meanwhile the oxidase activities were further reduced with the presence of TO in CECE. These findings were supported by previous works by Guerreiro et. al. [20], which stated that the edible coating had potential in maintaining the fruits organoleptic properties.
Figure 4. Average Oxidase Activity of Fresh-Cut Fuji Apples for 1, 3 and 5 Days.

3.5 Surface morphology of coating

Figure 5 shows the surface morphology of fresh-cut Fuji apples for (a) 60, (b) 180 and (c) 300 s dipping time. The irregularities of surface coating film were observed for all samples. This is due to the presence of various polymer molecules in matrix-based polymer [21]. It can be seen in Figure 5 (a) and (c) that there were presence of large holes and cracks on few parts of the coating which affect the respiration rate that led to the loss of weight, firmness and moisture content. The percentage surface area without cracks and holes for (a) is 66.3% while (c) is 75.4%. While in Figure 5 (b) for the surface of 180 s dipping time, there were presence of little cracks and small holes, and it had smoother surface compared to 60 s and 300 s dipping time. Furthermore, the percentage of surface area without cracks and holes were larger compared to the other two dipping time which is 89.1%. Therefore, this could be the reason that weight loss and firmness loss for this condition were the lowest among others. This finding was similar to previous work carried out by Ruzainah et. al. [15].

Figure 5. Microstructure of surface morphology for 17.5 μL/mL of TO (a) 60 s, (b) 180 s and (c) 300 s.

4. Conclusion

Findings obtained from the study presented that the coated fresh-cut Fuji apples incorporated with 17.5 μL/mL TO had the lowest weight loss (0.898 g) and firmness loss (18.38%) compared to other conditions. Meanwhile, coated apples with 60 s dipping time and 17.5 μL/mL TO had the lowest
moisture loss (82.61%) and oxidase activity. From the surface morphology analysis, it can be concluded that 180 s dipping time had the most covered surface (89.1%) compared to other dipping time. The composite edible coating emulsion can be huge potential as fresh-cut fruits coating to preserve the quality of the fruits.

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