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Research paper

Effect of Dipping Time and Weight Loss of Fresh-Cut Apple using Polysaccharide Composite Edible Coating

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Abstract

Composite edible coatings were made up of cassava starch and carboxymethyl cellulose (CMC) incorporated with turmeric oil (TO) as an antioxidation agent. Gas chromatography-mass spectroscopy (GC-MS) analysis was done to determine the present of secondary metabolite compounds which will act as the antioxidation agent. Fourier Transform Infrared (FTIR) spectroscopy analysis results showed that the functional group in turmeric oil that acts as an active compound was present in the edible coating film. Surface tension and wettability analyses were done to determine the right amount of starch. The best formulated edible coating formulation was S2 that was in the range of the general rule of surface tension and spreading coefficient was near to zero (-20.70 ± 30.76 dyne/cm). The characterization on the effect of dipping time and turmeric oil towards weight loss of fresh-cut apple gave results that 180 s dipping time with 175 ppm of turmeric oil concentration had the lowest weight loss value.

Keywords: *Dipping time; edible coating; fresh-cut apple; turmeric oil; weight loss.*

1. Introduction

Nowadays, consumers are more aware of the significance of having the healthy diet. However, associated with their modern and busy lifestyle, they prefer more of the readily-prepared food for their diet routine. This is including the demand on the fresh cut fruits [1]. Consumers realize that eating fruits can help to prevent the various types of illness such as cancer and cerebrovascular due to the high content of antioxidants in these fruits [2]. The commercialization of fresh cut fruits has its limits due to their minimal shelf life period and is easy to deteriorate. These problems have become the main factor that affect the economics of fresh cut fruits industry [3]. The process of peeling and cutting the fruits will lead to the structural damage of the cell and tissues. Besides that, it also will increase the production of the ethylene which will accelerate the ripening process [4]. The quality of fresh cut fruits will decrease due to the decaying process that involves the oxidation process which easily occurs with the presence of oxygen from the surrounding (enzymatic browning), dehydration, microbial spoilage and production of unpleasant tastes and odours [5].

In order to extend the shelf life of the fresh cut fruits, various techniques of preservation have been introduced either by using the conventional or modern method. Some of these techniques use the additives to help the preservation process more effective [6]. However, in this study it will only focus on the preservation technique by using edible coating film and it will be incorporated with turmeric oil that acts as antioxidation agent which will inhibit or postpone the enzymatic browning from occurring. For the purpose of this study fresh cut apple (Fuji Apple) will be used. This is because some of the edible coatings nowadays are still lacking to maintain the fruit stability and quality. Besides that, dearth of study conducted on turmeric oil as an antioxidation agent.

Edible coatings are thin films that enhance fruits and vegetable quality and can be securely eaten as a component of the fruits and vegetable [7]. In spite of the fact that the terms edible films and coatings are sometimes pointed out as equivalent words, there is a distinction in that films are preformed separately and after that, it will be applied to the surface of foods, while coatings are coated straightforwardly onto food surfaces[8]. The uses of edible coating are becoming important as it can protect the food and had more advantages compared to using the synthetic edible coating film.[9] Edible fresh cut fruits coating can be made from different bases of coatings such as polysaccharide, protein, and lipids [10]. There are various types of natural polymers that have been applied as fruit and vegetable coatings such as whey, bees wax, chitosan, starch, alginate and many others [11], [12], [13], [14]. Besides using only one type of basic constituent, edible coating can be made up from the mixture of those three group basic constituents and also other additives. This edible coating is known as composite edible coating [15], [16].

The composite edible coatings that are used in the present study are the mixture of cassava starch and carboxymethyl cellulose. Starch is the depository of polysaccharide of legumes, tubers and cereals. It is the renewable source and the raw materials that is easily to be found. Besides that, it is also convenient to be used in various type of industry [17]. Starch consists of polymer that is made up from D-glucopyranosyl. This polymer is consists of the mixture of linear amylose and branches of amylopectin. Amylose and amylopectin are being connected with hydrogen bonds and the starch molecules will organize themselves in semi crystalline granules. Granules will be hydrated and swell due to the heating of starch in the existence of water. Thus, they will lose the arrangement of molecular order and increase the viscosity of the solution [8]. Starch is a carbohydrate that is normally found in the plants tuber and seed endosperm. Amylose that is present in starch is responsible for the film-forming capacity of starch [18]. Cassava starch is being used for coating fresh cut fruits due to its flexible, odourless, non-toxic and tasteless characteristics. It has low water permeability and have abundant of resources. It also has the ability to produce continuous matrix and is renewable [19], [20]. However, starch cannot be used without reinforcement materials due to its brittle characteristic, poor mechanical properties, intractable nature and water sensitivity which makes it can be fragile even with the presence of low water content [19], [21]. To overcome this problem plasticizer is added to the formulation. Concentration of plasticizer that is used is commonly in the range of 10-60 g / 100 g depending on the severity of the polymer [19].

The aims of this research are 1.) To analyse the composition of secondary metabolites compounds in extracted turmeric oil, 2.) To formulate polysaccharide composite edible coating with turmeric for fresh cut apples through surface tension and wettability analyses, and 3.) To characterize the effect of dipping time and turmeric oil concentration towards weight of fresh cut apples.

2. Materials and methodology

2.1. Materials

Fresh Fuji apples were obtained from the local market in Shah Alam, Selangor, Malaysia. And they should have regular shape, similar in size without any defects and be half ripe [22]. Fresh fruits were cut into wedges by using an apple cutter. Cassava flour (Cap Kapal ABC.Co) and carboxymethyl cellulose (Novelecell, Malaysia) were used as biopolymer for composite coating or bilayer coating materials. Citric acids (Merck, United State) served as the cross linking agent. Glycerol (Merck, United State) was used as plasticizer and turmeric oil (Soul, Malaysia) was used as antioxidation agents. Lastly, 1.0 M sodium hydroxide (R&M, Malaysia) was used in neutralizing the pH of emulsion.

2.2. Preparation of turmeric oil

Hydrodistillation method was used to extract the turmeric oil. Turmeric's rhizome was bought from the local market in Selangor. The fresh rhizomes were washed and dried by using paper towel. The 200 grams of fresh rhizomes were sliced into round shape [23].The clevenger apparatus was used to extract essential oil by using hydrodistillation method. The sliced fresh rhizome were placed in 1000 mL of round flask with 500 mL of distilled water for 4 hours. The oils was kept in a dark colour bottle at room temperature [24].

2.3. Edible coating preparation

The amounts of 5, 6, 7, 8, and 9 grams cassava starch was diluted in 100 mL of distilled water for 40 minutes at temperature 80^{o}C. Then, 0.5 grams of 0.5 M citric acids was added in the emulsion as the cross linking agent. The 2 mL of glycerol was added in the emulsion as plasticizer to improve the flexibility of the coating film. After that, 2 gram of carboxymethyl cellulose (CMC) was solubilized in 100 mL of distilled water (DW) for 30 minutes at 75^{o}C. It was stirred them at a temperature 75^{o}C for about 30 minutes in order to achieve homogenous stated. The emulsion pH was altered with standard alkaline solution (0.1 M sodium hydroxide) to pH value 5.6 [25]. The emulsion was cooled down at 40^{o}C and stirred slowly for 20 minutes in order to release all the air bubbles. Lastly, 175 ppm concentration of turmeric oils (TO) was added into each 100 mL of emulsion and the fresh cut apples were dipped into the formulation for a few seconds by using dip coater machine and dried. The samples were stored in the chiller at temperature of 6^{o}C.

2.4. Gas chromatography-mass spectroscopy (GC-MS)

The chemical composition of component in turmeric oils was analysed through. This research procedure was done according to Wahab *et. al.* [26]. The temperature of GC-MS injector was set at 100^{o}C by using the splitless mode and 1.0 µL of turmeric oil was injected into it. The helium gas was then used in the GC-MS as the carrier gas with the flow rate of 5ml/min and 12.936 psi of inlet pressure condition. Afterwards, the percentage compositions of turmeric oil were analysed using standard reference compound. The mass spectra pattern was then identified according to Mass Spectra Library which had been stored in GC-MS database.

2.5. Fourier Transform Infrared (FTIR) Spectroscopy

The functional groups of extracted turmeric oil was analysed through Perkins Elmer 100 FTIR. The functional groups and molecular interaction spectra were reported in % transmittance. The wavelength range for analysis was 4000 to 400cm^{-1}.

2.6. Surface tension and wettability

Surface tension is the number of energy needed to raise the surface per unit area while wettability is to ascertain the formulation ability to spread, its adhesion and also cohesion work [27], [28]. Surface tension and wettability were measured by using Contact Angle Goniometer (AST Products, INC.) using sessile drop method to measure the contact angle. The formulation was dropped on the surface of fresh cut apples and recorded by Contact Angle Goniometer video so that the perfect contact angle was able to capture on time. Surface tension was calculated using the surface energy software (SE2500) while wettability was determined using the equation below. Ws is the spreading coefficient, Wa is the work adhesion and Wc is the work of cohesion [29]. The formulation is taken with 5 mL syringe with 0.75 mm diameter of needle [30].This process is repeated for four times for each of the formulation. To obtain Ws, contact angle (Θ) and surface tension (γ) were determined.

$$Ws = Wa - Wc \quad (1)$$

$$Wa = \gamma L\ (1+\cos(\Theta)) \quad (2)$$

$$Wc = 2\ \gamma L \quad (3)$$

2.7. Weight loss

Fresh cut apples were dipped into the coating formulation, then it left to drain for 1 hour using a fan at room temperature. The fresh cut fruits were weighed on the digital balance to record weight loss and the total weight loss was calculated by using equation (4), where Weight (i) was the weight of fresh cut apples initial and Weight (f) is the final weight of the fresh cut fruits. The weight reading was taken three times. The samples were weighed for five days [31].

$$\text{Total weight loss} = \text{Weight(i)} - \text{Weight(f)} \quad (4)$$

3. Results and discussion

3.1. Chemical composition of extracted turmeric oil

Turmeric oil was analysed through Gas Chromatography- Mass Spectrometry (GC-MS) analysis and the percentage composition of compounds were listed in the Table 1. There were fifty components that were presence in extracted turmeric oil. However, only compounds that high in peak area or composition percentage and capable to act as antioxidation agent were listed out and tabulated in Table 1. The prevailing compounds in turmeric oil were ketonic sesquiterpenes compounds which are turmerone (35.462±0.07%), Ar-turmerone (13.821±0.02%), cumene (20.612±1.38%), curlone (3.114±0.04%) and curcumene (0.434±0.02%) and also the aliphatic monoterpene which is cymene (0.895±0.06%). These compounds constituted 74.368% of the total oils. Sesquiterpenes are the majority compounds that can be found in turmeric oils especially turmerone. This outcome was also observed from previous studies Awasthi and Dixit [32] and Jelena et. al. [33] they stated that, the major compounds that can be found in turmeric oil that extracted from rhizomes were ar-turmerone (31.7%), α-turmerone (12.9%) and ß-turmerone (12.0%).

Essential oils that act as antioxidation agent had the properties in donating the hydrogen atoms that commonly from hydroxyl group. Therefore, it will break the free radical chain reaction [34]. As in the present extracted turmeric oil analysis, it shows that hydroxyl functional group does not appeared in the compounds with high percentage composition which can be seen the molecular structure of the in the Fig 1. However, with the presence of turmerone and Ar-turmerone in the extracted turmeric oil shows that it is able to be used as antioxidation agent. This finding was confirmed by Jelena et. al. [33] which stated that, turmerone and ar-turmerone also had the ability as antioxidation agent. It shows that the present of turmerone and Ar-turmerone will enhance more the properties of this turmeric oil as antioxidation agent especially in donating hydrogen atom.

Table 1 : Percentage composition of compounds found in extracted turmeric oil

Compound Name	Rentation Indices	Peak area (%)
Curcumene	28.709	0.434 ± 0.02
Curlone	34.690	3.114 ± 0.04
Ar-Turmerone	35.822	13.821 ± 0.02
Turmerone	35.996	35.462 ± 0.70
Cumene	37.151	20.612 ± 1.38
Cymene	39.074	0.895 ± 0.06

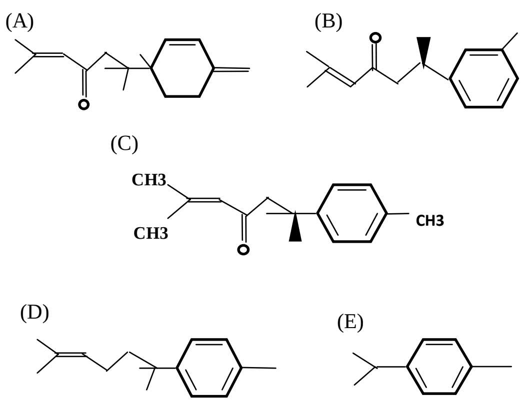

Fig. 1: Molecular structure of the presence compounds (A) curlone; (B) Ar-turmerone; (C) turmerone; (D) curcumene and (E) cymene

3.2. Fourier Transform Infrared (FTIR) spectroscopy analysis on turmeric oil

Turmeric oil (TO) be used as the antioxidation agent in producing the composite edible coating film due to high presence of secondary metabolites compound in it. TO chemical functional groups were analysed by using Fourier Transform Infrared (FTIR) Spectroscopy. This analysis was done in order to ascertain the functional groups that can act as antioxidant agent. From Fig. 2 below, it shows that, hydroxyl group was attributed at the wavelength 3456.26 cm^{-1}. Furthermore, at the wavelength 1376.77 cm^{-1} it showed that phenol group were present. Hydroxyl groups had the potential to act as the antioxidation agent in order to inhibit the enzymatic browning. Aromatic ring functional groups were appeared at the peak 3456.26 cm^{-1} (C-H stretch), 1515.57 cm^{-1} (C=C bending), 1445.57 cm^{-1} (C=C stretching), 1234.50 cm^{-1} (C-H), 1178.80 cm^{-1}(C-H), 878.27 cm^{-1}(=CH (out of plane)) and 815.79 cm^{-1}(=CH (out of plane)). Whereas, alkene groups were exhibit at the wavelength of 2961.29 cm^{-1} (-CO-CH3 (weak bond)), 2928.88 cm^{-1} (-CHO (weak bond) and -CH stretch), 1445.57 cm^{-1} (C-H stretch), 1376.77 cm^{-1} (-C-H) and 983.41 cm^{-1} (-CH bending). Therefore, with the existence of hydroxyl group in turmeric oil, it prove more that turmeric oil can be used as antioxidation agent of fresh-cut 'Fuji' apples. This is in agreement with similar finding reported by V. Surwase et. al. [35].

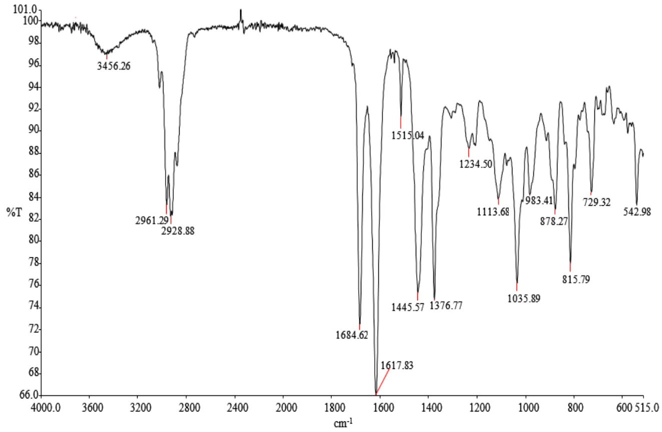

Fig. 2: Spectrum analysis on functional group of turmeric oil (TO)

3.3. Surface tension and wettability

Table 2, shows that by increasing the cassava starch, the surface tension reading were decreased. It can stated that starch has non-Newtonian fluid properties because it can reduced the surface tension of water from 72.75 dyne/cm to 44.64 dyne/cm, 37.92 dyne/cm, 36.10 dyne/cm and 35.89 dyne/cm, 34.39 dyne/cm. The surface tension value for formulation of S2 until S5 gave the results that is within the range of general rule of surface tension for fruits coating which is 28 to 38 dyne/cm. It has being confirmed by Cothran (1945) [36] in order to have the constant uniformity of coating, emulsion surface tension should be in in between general rules range 28 to 38 dyne/cm. The surface tension of the emulsion was decrease with increasing the amount of cassava starch used. However, the formulation of S2 was chosen to be used in formulate the composite edible coating emulsion. This is because higher amount of starch will tends to have incomplete gelatinization process and produce thicker emulsion while the lower amount of starch will lead to uncompleted formation of edible coating film. This findings was in agreement with C. Pagella et. al. [37] research study on characterization of starch based edible coating. Fig. 3, shows the spreading coefficient (Ws) of S2 had the nearest value to zero compared to others because if the value of Ws zero, it shows the complete coating of fresh-cut 'Fuji' apples. The closer the Ws value to zero the better the spreading of solution on the surface of fresh-cut 'Fuji' apples and the value should be in negative formed. This was agreed by Cerquira et. al. [38] and Bonn et. al. [39] which stated that the Ws value should be in negative formed due to the value is known as equilibrium spreading coefficient. Besides that, it also showed that the S2 had the highest value of work of adhesion (Wa) which means it capable to attached on the surface of fresh-cut 'Fuji' apples more compare to others. Similar trends of results were found out by Cerquira et. al. [38] for coating Acerola by using galactomanan and glycerol as raw materials. However, the work of cohesion for S2 was high compared to S3, S4 and S5. High work of cohesion causes the formulation to have low ability to shrink on the surface of fresh-cut 'Fuji' apples flesh. This can be concluded that 6 (%w/v) cassava starch of distilled water were used in formulate the starch composite edible coating.

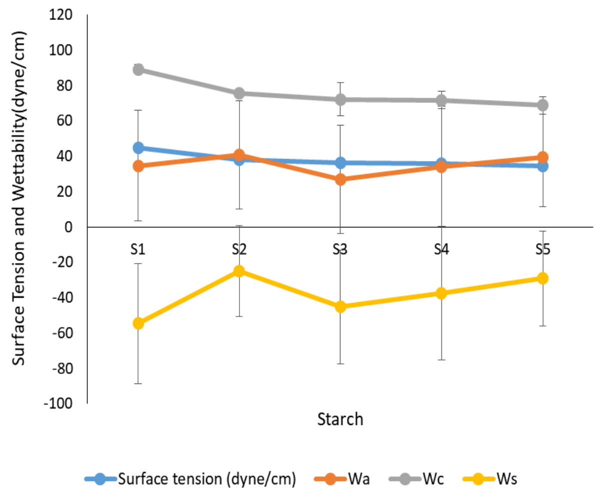

Fig. 3: Surface Tension and wettability against different amount of starch

3.4. Weight loss

The formulated edible coating emulsion were applied on the surface of fresh-cut apple to determine the ability of the edible coating in retained the weight loss of the fresh-cut apple.. The weight loss of coated apples with and without TO, and uncoated fresh cut apples (control) were measured every day from day 0 to day 5 by using laboratory digital balance. The coated apples were dip in the emulsion for 60, 180 and 300 s of dipping time. Results, as shown in Fig. 4, shows that the uncoated (control) fresh-cut apples had the highest total weight loss compared to the coated fresh-cut apples. This may due to high in water loss between the fresh-cut apples tissues and the surrounding which cause the fresh-cut ‘Fuji’ apples to dehydrate. Similar finding has been obtained by Petriccione et. al. [44] and Guerreiro et. al. [45] stated that fruits hydration occurred due to the moisture loss from the fruits to surrounding . The coated fresh-cut apples had lower weight loss due to the presence of hydrophobic compounds in the starch based composite edible coating. Additional of citric acids as cross-linking agent into the starch based composite edible coating is one of the factor that contributed the hydrophobic coating film properties. Thus, it can diminishing the fresh-cut apples weight loss. This finding was supported by Hirashima et. al. [46] which stated that the additional of citric acid in corn starch emulsion could change the properties of corn starch from hydrophilic to hydrophobic. In the indicated graph, 0ppm of turmeric oils had the highest weight loss compared to others coated samples. This can be indicated that additional of turmeric oil in the starch based composite edible coating had the ability in reducing the weight loss of the fresh-cut apples. Besides that, it shows that 175ppm of TO at 180 seconds of dipping time had the least total weight loss compared to all coated fresh-cut apples. The 60s of dipping time for all turmeric oil concentration shows that it has high weight loss compared to 180s. This indicate that the lower dipping time of the fresh cut fruits in formulation would not capable in retain the weight loss as it is unable to control the respiration rate of fresh-cut apples due to thin coating thickness. Similar finding was found out by Jerry et.al [47]. However, weight loss at 300s of dipping time for all concentration was higher compared to 180s. This is believed to occur due to the thicker thickness of the starch composite edible coating as the anaerobic condition take placed in the fresh-cut apples. Besides that, it may also occur due to the hydrophilic nature of the starch. The similar trend for this results can be seen in Sudhanshu and Hari [48] and Jerry et.al [47] research studies. This can be concluded that 180s of dipping time is the maximum dipping time for fresh cut apple for this research study because it can produce the desire thickness that can retain the quality of fresh cut apple.

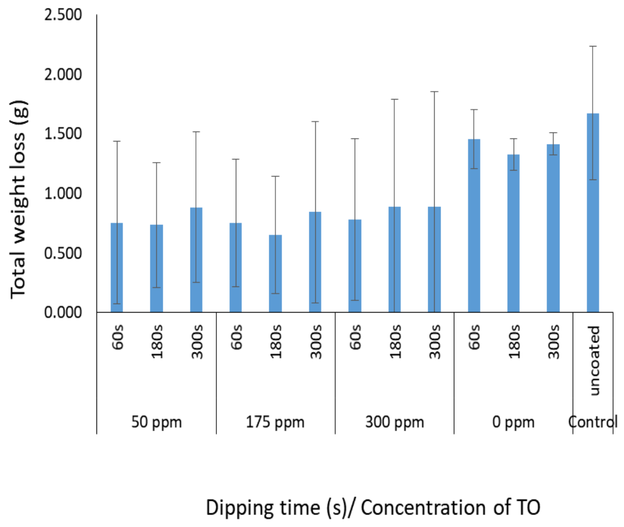

Fig. 4: Total weight loss of fresh-cut “Fuji’ apples for 5 days

4. Conclusion

Results obtained from the research study showed that from the GC-MS analysis, the turmeric oil was capable to be used as an antioxidation agent with the presence of secondary metabolites compounds such as turmerone, ar-turmerone, curlone, cymene and curcumene. Hydroxyl group is the most important functional group that can act as antioxidation agent. However, the presence of hydroxyl group could not be traced using GC-MS but it can be traced in FTIR analysis. This proved more that the extracted turmeric oil had the capability to act as a natural antioxidation agent. From the surface tension and wettability analyses it can be concluded that S2 formulation had surface tension value in the range of general rule and had the best spreading coefficient. Meanwhile, when the edible coating was applied on the surface of fresh-cut apples, the weight loss of fresh-cut apples for 175 ppm of TO with 180 seconds of dipping time has the least compared to others concentrations and dipping time. This can be concluded that, this study indicates the use of edible coating incorporated with turmeric oil can help in preserving the quality of fresh-cut apple.

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Table 2 : Analysis of surface tension and wettability of composite edible coating for different amount of starch

Formulation.	Starch (%w/v) DW	Glycerol (%v/v) DW	Citric acids (grams)	CMC (%w/v) DW	Surface tension (dyne/ cm)	Wettability (dyne/cm) (Mean ±SD)		
						W_a	W_c	W_s
S1	5	2	0.5	2	44.64	34.59 ± 31.32	89.29 ± 2.77	-54.69 ± 33.81
S2	6	2	0.5	2	37.92	40.66 ± 30.68	75.84 ± 1.83	-25.04 ± 25.72
S3	7	2	0.5	2	36.10	26.99 ± 30.75	72.21 ± 9.36	-45.21 ± 32.30
S4	8	2	0.5	2	35.89	34.25 ± 33.83	71.79 ± 5.00	-37.54 ± 37.64
S5	9	2	0.5	2	34.39	39.61 ± 28.22	68.79 ± 4.89	-29.17 ± 26.75

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