Turmeric Oil as Antioxidation Agent for Fresh Cut Fruits

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***Abstract*— Nowadays, people are more aware of the healthy eating habit and therefore, due to safety reason, the demand to use natural additives as antioxidation agents for fresh cut products like fresh cut fruits is increasing. This is because the use of synthetic and chemical preservatives has gained a lot of attention to the public since some of it causes odd allergic reactions towards sensitive individuals. Furthermore, the basis appearance of the fresh cut product like fresh cut fruits has to be appealing during the time of purchase because it will be judged by the customer and the appearance of the fresh cut fruits will be the decision-maker for the customer on whether to buy the product or not to buy it. In this research project, edible coating was used to prevent the enzymatic browning of the fruit (apple) that caused by the Polyphenol Oxidase (PPOs). Starch and glycerol were used in the formulation of edible coating film and turmeric oil was added as the additives. Turmeric oil is one of the antioxidation agents that come from spices and herbs. With a ratio of starch:glycerol, 1:0.25, turmeric oil was added to the formulation and homogenized. Then, the prepared apple slices were dipped into the emulsion and the coated and uncoated apple slices were stored and compared afterwards. The coated and uncoated apple slices were compared by their weight loss, color changes and sensory evaluation. Also, the degree of oxidation were characterized using the assay for PPO activity method.**

***Keywords*— Turmeric Oil, Fresh-Cut Fruits, Edible coatings, Apple, Antioxidation Agents**

I. Introduction

Fresh cut fruits are basically fruits that has been trimmed or reshaped from its original state, (ex; cut and peeled) to become another usable products but still remain in its fresh state. Commonly, fresh cut fruits will offer a highly nutritious and health commodities to the consumer. However, it is hard to maintain its fresh state mainly due to the removal of their pure vigilant skin and the damage caused to cells and tissues by cutting and trimming (Watada and Qi, 1999). The tissue of the fruits will become wounded and it will lead to the negative effects on the product quality such as enzymatic or oxidative browning, production of undesirable flavours and odours and texture breakdown. It will also shorten their shelf-life due to their high rate of deterioration. Nowadays, consumers are more conscious about the importance of healthy eating habits. Therefore, the basis appearance of the fresh cut fruits such as the size, shape, form, colour, condition and the freshness during the time of the purchase will be judged by the consumer.

Enzymatic browning is one of the most essential reactions that occur in many fresh-cut fruits especially for white-fleshed fruits such as apple and pears. Polyphenol oxide (PPO), which is a copper-containing oxidoreductase is basically what driven the browning reactions to occur where it catalyzes two different reactions involving phenolic compounds and oxygen. Through this reaction, O-quinones will be developed from the oxidation of O-diphenols and will lead to the build-up of melanin and the development of brown or black-coloured compounds depending on the specific structure of the polyphenolic substrate (Queiroza et al., 2008). Accordingly, there are ways to inhibit the enzymatic browning of the fresh cut fruits where the fruits will be dipped or coat with edible coatings where it contains antioxidation agents such as turmeric oil. The application of the oxidation agents is to maintain the freshness of the fresh cut fruits and to improve the quality and functionality of fresh cut fruits (Maria, Robert and Olga, 2009).

Antioxidation agent is needed to prevent the enzymatic browning towards the fresh cut fruits by prohibiting the initiation of browning by reacting with the oxygen. In other words, when any element or compound combine or react with oxygen, it is called as oxidation. When oxidation process happening, it will lead to the formation of melanin and hence the browning of the fresh cut fruits occurred. By reacting with the oxygen itself and any intermediate products, antioxidation agents will interrupt the free radical chain reaction and prevent the formation of melanin (Lindley, 1998). Usually, the fresh cut fruits will be dipped or coat with an edible coating to cover the surface of the fruits to maintain its freshness and improve the product quality and the fruits can be eaten as a part of whole food (Raghav, Agarwal and Saini, 2016).

Ascorbic acid is one of the most widely used antioxidation agents in preserving the fresh cut fruits from the browning effect. It has been widely used as antioxidation agent for processing fruits because it can reduce the O-quinones that are produced by PPO-catalysed oxidation of polyphenols, back to dihydroxy polyphenols. Yet the effect of ascorbic acid is actually temporary because once it is added to the fruit by coating or dipping technique, fruit will completely oxidised and O-quinones could accumulate, thus leading to browning pigment formation (Ozoglu and Bayindirli, 2002; Jang and Moon, 2011). Other compounds that are frequently used as antioxidation agents for edible coating to extend shelf life for fresh cut products are chitosan, starch, cellulose, alginate, carrageenan, gluten, whey, carnauba, beeswax and fatty acids (Gonzales et al., 2010).

Nowadays, due to the safety concern of the use of the synthetic antioxidation agent, there is an increasing demand from the consumer to use natural antioxidants. Consumer these days preferred natural products, clean label and lesser usage of food additives in food products (Embuscado, 2015). Several studies in the literature have revealed that spices and herbs can be natural sources of antioxidation agents to due to their natural antioxidant components. Few examples of natural antioxidation agents are ginger, chilli pepper, rosemary and turmeric (Embuscado, 2015). For example, in turmeric, antioxidant compounds are found (Curcumin and 4-Hydroxycinnamolymethane) and it has high antioxidants activities that will help in reducing the browning of fresh cut fruits.

Turmeric, which is also known as Curcuma Longa is contemplated as one of the golden resource with massive export potential as medicine, beauty aid, cooking spice and a dye (Das, 2016). Turmeric is also known for its health promoting properties. Essential oil components can be extracted from the turmeric and the yield of the turmeric oil that can be extracted from leaves ranges between 2.75-2.83%. Meanwhile, when turmeric oil is extracted from the rhizomes, the yield of turmeric oil obtained is 2.38-2.48% (Chandra, Prajapati, Garg and Rathore, 2016).

Turmeric oil has been showing antifungal, antibacterial and antioxidant properties and most of the turmeric oil components are bisabolane type sesquiterpenoids (Tzortzakis, 2007). Turmeric oil inhibits the growth of variety of bacteria, pathogenic fungi and parasites. Also, due to its antioxidant activity from the antioxidant compounds found (Curcumins and 4-hydroxycinnamoyl methane), turmeric oil helps in inhibition of oxidative deterioration for the fresh cut fruits and thus, making it as one of the natural sources of antioxidation agent. The application of edible coatings from the turmeric oil and the use of turmeric oil as antioxidant, antibrowning and texture enhancers to improve the quality and functionality of fresh cut fruits will be further reviewed.

II. MATERIALS AND METHODOLOGY

Materials

Chemicals that were used in this experiment, which were starch, glycerol and turmeric oil are food grade chemicals. This is to ensure that the data that obtained from this experiment are decent with minimal errors which could come from the impurities of the chemicals.

The raw material used in this study was apple. Apple was purchased from the local market located in Shah Alam prior to start this experiment. Undamaged apple in uniform size and similar maturity stage will be selected.

Coating Preparation

At 70 ◦C with constant stirring, starch (2% and 3% w/v) was dispersed in an aqueous solution and will be prepared. Ratio of starch: glycerol ratio will be at 1:0.25, and glycerol was added after starch's gelatinization. Afterwards, essential oil which was the turmeric oil (0.05% to 0.30% v/v) was added to starch suspensions and homogenized with stirrer for 5 minutes at 16000 rpm (Oriani et al., 2014).

Preparation of the Apple Slices

The apples that were bought from the local market at Shah Alam was cleared up by cleaning it and sorted to remove damaged apples and foreign materials. After that, apples with identical size, shape and color will be chosen. The apples will then be stored in a room temperature and soak thoroughly with tap water to remove any surface dust or any impurity. The apples were cut with a stainless steel knife in equal slices of 1.5 cm in length to minimize browning (Shahnawaz, Wali and Abbass, 2013). Apples will be divided into two parts, trays containing apples coated with emulsion formulation and trays containing apples without coating for blank and then stored in a refrigerator with 4◦C.

Coating Application

Coating was applied using the emulsions at room temperature. Apples were dipped in the emulsion for 30s and then dried at room temperature by fanning the apple product with a table fan and after that the apples were held at refrigerator (4℃). About 30ml of emulsion was used to coat each kg of apples and the coating became transparent and almost invisible after drying (Shariatifar and Jafarpour, 2013).

Weight loss determination

The weight losses of non-coated and coated apples during storage were compared. Weight loss in this matter happened because of the water loss during storage. Weight loss was disclosed as percentage decrease in fruit weight, using the following formula $(W_t / W_0)*100$, with W_0 being the initial weight and W_t being the fruit weight after a designated period of storage. (Hassan, Lesmayati, Qomariah and Hasbianto, 2014)

Colorimetric determination

Color was measured using a colorimeter HUNTERLAB-D25-9000 to obtained CIE values (L*,a*,b*). The subscript 0 in the equation stand for the color parameters of fresh apple slices. The greater the total of ΔE, it represents greater color transition from the fresh apple (Seiiedlou et al., 2010).

$$\Delta E^* = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{1/2}$$

Sensory Evaluation

For the sensory evaluation, coated and uncoated apples were analyzed. Ten sensory panelists were picked and for each sensory test panel, in coded dishes, samples containing coated and uncoated apples were given. The panelists were given a hedonic questionnaire to test appearance and surface color of coded samples of apples. Table 1 and Table 2 below were the sample for the hedonic questionnaire and the scoring scale (Shariatifar and Jafarpour, 2013).

Table 1 shows scorecard of hedonic rating scale (Ackbarali and Maharaj, 2014)

<table>
<tr><th colspan="2">Scorecard- Hedonic Rating Scale</th></tr>
<tr><td>Dish Number:</td><td>Name:</td></tr>
<tr><td colspan="2">In front of you are the samples of coated and uncoated apple slices inside a numbered dish. Please rate the apple inside the dish according to the scale given below:</td></tr>
<tr><td colspan="2">Food Characteristics</td></tr>
<tr><td>Appearance</td><td>Surface color</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 2 shows scale and description for the scorecard of hedonic rating scale (Shariatifar and Jafarpour, 2013)

Scale	Description
5	Excellent
4	Very Good
3	Good
2	Fair
1	Poor

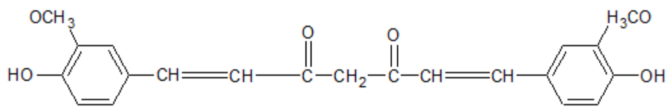
Methods to Monitor Enzymatic Browning Oxidation (Assay for PPO Activity)

Enzymatic activity was assayed by checking the rate of increment in absorbance at a range of 420nm and at 25°C in a double beam model UV-1601 UV/VIS spectrophotometer. The reference cuvette has only the substrate solution. Meanwhile, the straight-line section of the activity curve as a function of time was used to figure out the enzyme activity (Units/g of fruit/min). A unit of enzyme activity was defined as the change of 0.001 in the absorbance value under the conditions of the assay (Galeazzi and Sgarbieri, 1981). When a lag phase happened, the reaction rate will be measured after the lag phase (Rocha and Morais, 2001).

III. RESULTS AND DISCUSSION

A. FTIR Analysis

Turmeric oil is one of the antioxidation agent that comes from spices and herbs and the turmeric extracts, the effective constituents that known as curcuminoids that is also known as curcumin, has been showing so much characteristics such as antioxidant, anti-inflammotary, antibacterial, antifungal and anticoagulant activity in animals (Bengmark et al., 2009; Martin et al., 2011; Singh et al., 2010).



Curcumin-I

Figure 1: Antioxidant compound in curcumin

As it can be seen in Figure 1, the functional groups that can be found in curcumin are alkane, alkene, alcohol, aromatic and ketone. Thus, an analysis of coating mixture contains 100ml distilled water, 5g of starch, 1.25ml of glycerol and 15μL of turmeric oil was done. The result can be seen on Figure 2 and Table 3 below. From the result obtained all the functional groups that contain inside the curcumin except for ketone were presence. However, the presence of alkane(C-H), alkene (C=C), alcohol (O-H, C-O) and aromatic ring (C=C) are enough to make them work as antioxidant.

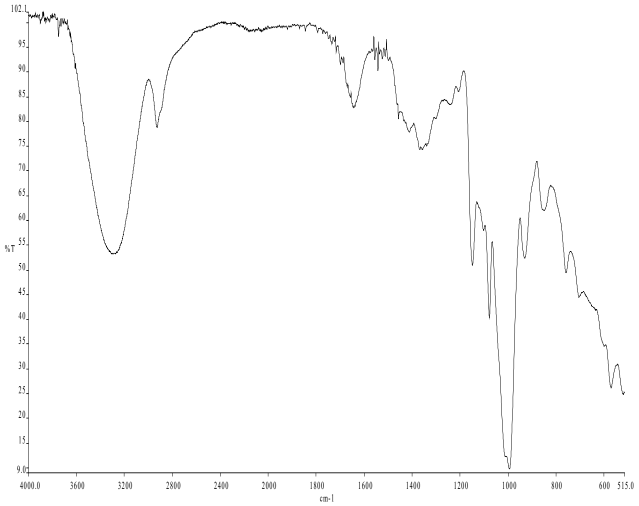


Figure 2: FTIR results for coating solution contained 15μL of turmeric oil

Table 3 shows the type of functional group inside coating solution containing starch, glycerol and turmeric oil

Functional Group	Type of Vibration	Characteristics Absorptions (cm^{-1})
Alcohol		
O-H	Stretch, H-bonded	3292.20
C-O	Stretch	1148.90
Alkane		
C-H	Stretch	2925.28
Alkene		
C=C	Stretch	1642.13
=C-H	Bending	931.64
Aromatic		
C=C	Stretch	1555.59
Ether		
C-O	Stretch	1077.73

B. Sensory Evaluation

Sensory evaluation has been done for the coated and uncoated apple cubes that were stored in a chiller for 12 days at 4℃. For the coated apple cubes, apple cubes that were coated with coating solution that contain 15μL turmeric oil were presented as a sample. A total of ten sensory panelists were gathered during 4th of May 2016 to evaluate the sample of apple cubes that were being presented in a coded dish labeled as A and B. The panelists were given a hedonic questionnaire to test the appearance and surface color of coded samples of apple cubes. Below are results from the sensory evaluation:

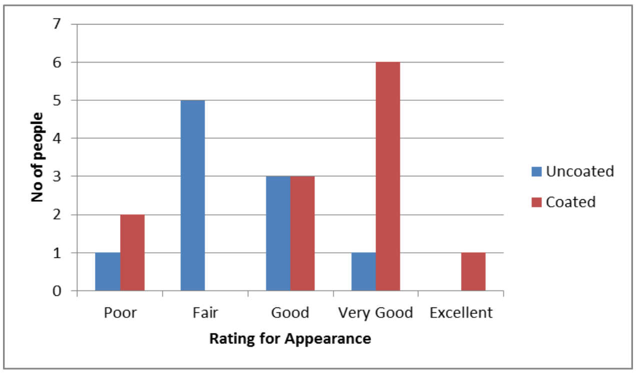


Figure 3: Rating for appearance of uncoated and coated apple cubes

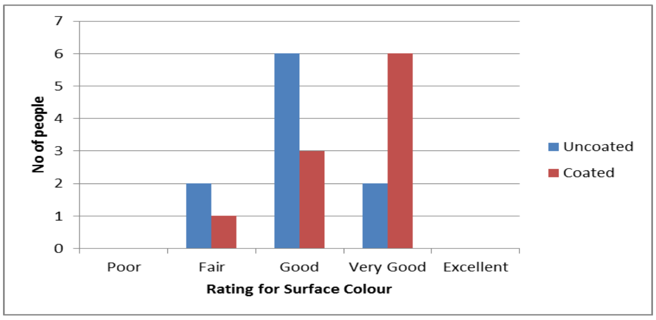


Figure 4: Rating for surface colour of uncoated and coated apple cubes

Based on Figure 3 and Figure 4 above, there are variety of ratings given from the sensory panelist. However, the ratings for the coated apple cubes were quite high both for the appearance and the surface color of the apple cubes. Six panelist rate the appearance to be in very good appearance and one panelist rate the appearance of the apple cubes as excellent. It can be conclude that even from the sensory evaluation, the appearance of the apple cubes that were coated with the turmeric oil seems to be having a great appearance towards the panelist. This proved that the turmeric oil can preserve the apple cubes from the enzymatic browning by using its antioxidant characteristics.

C. Weight loss

The percentage of weight loss for apple cubes with different type of coating at their sixth day and twelfth day of storage were shown in Figure 5. All apple cubes with different type of coating were being stored inside a chiller at 4℃ being covered with a plastic container with few holes on top of it. By covering the samples with plastic cover, it will also help to reduce the weight loss of apple cubes. Analysis of divergence showed that apple cubes being coated with 15μL turmeric oil presented notably the lowest weight loss at their sixth and twelfth day with 1.98% (sixth day) and 3.95% (twelfth day) compared to other apple cubes, whereas, apple cubes that were uncoated had no significant effect on the weight loss since the percentage of their weight loss on their twelfth day (11.85%) is quite high. Moreover, the effect of using the turmeric oil can be seen through the weight loss where apple cubes that were being coated with turmeric oil, even the smallest concentration, showed lesser weight loss compared to the apple cubes that were being uncoated and coated without turmeric oil.

At the same time, it can be seen that the higher the concentration of turmeric oil being used in a coating solution, the lower the weight loss occurred to the apple cubes. This shows that coatings that contained even the slightest amount of turmeric oil played an important role in avoiding weight loss of apple cubes, meanwhile coating that does not contain turmeric oil (only contain starch and glycerol) showed poor moisture barrier. According to Vander-Beng (1981), moisture loss from the fruits is serious consideration which decreases the visual quality and contributes to the loss of turgor pressure and consequent softening.

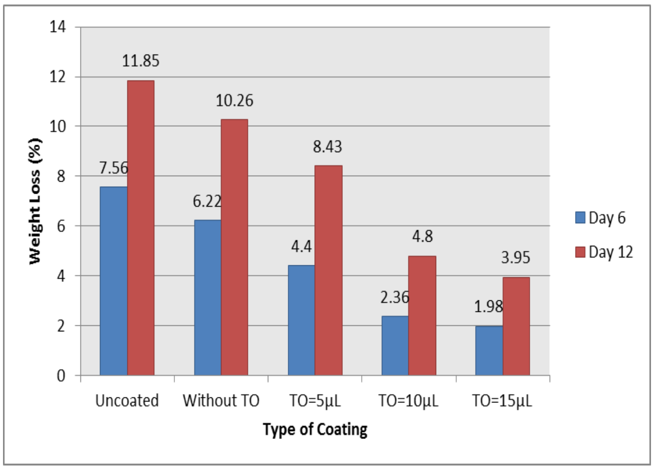


Figure 5: Type of coating for apple cubes

D. *Color Measurement*

The effect of the turmeric oil used in the coating solution can be monitored through the enzymatic browning of the fresh cut fruit (apple). Meanwhile, the enzymatic browning can be monitored through the color changes occurred on the apple. Color changes can be determined instrumentally by using a colorimeter with a L*a*b* coordinates. The colorimeter will give the measurement that can equate with the human eye-brain image and give tristimulus (L*, a* and b*) values directly (HunterLab, 1995). Colorimeter is desirable for routine quality control measurements.

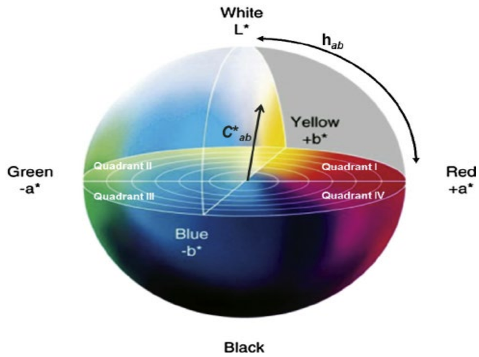


Figure 6: CIELAB sphere (Voltaire, Poliana, Ligia and Isabel, 2013)

There are different color spaces existed such as CIEXYZ, CIEUVW and CIELUV, but among the different existing color spaces, CIELAB is currently used and favored to be used on most industrial applications, especially for foods since it evenly covers the full visible spectrum of the human eye (Voltaire, Poliana, Ligia and Isabel, 2013).

As shown in Figure 6, color space may be divided into a three-dimensional (L*, a* and b*) where L axis that represent the lightness goes vertically from 0 (perfect black) to 100 (perfect white) in reflectance or superlative clear in transmission (HunterLab, 1996; Leggett, 2004). Meanwhile, the a axis (red to green) regarding the positive values as red and negative values as green, whereas, 0 is neutral. The b axis (blue to yellow) expresses positive values as yellow and negative values as blue; 0 is neutral. Fruits and vegetables are often described in terms of their L, a, and b values (Barrett, Beaulieu and Shewfelt, 2010).

The apple cubes were stored in a chiller with a mean temperature of 4℃ for a few days. It is being stored in a plastic container with a several holes at the top cover. Since the apples were dipped into difference concentrations of turmeric oil, the apple cubes were being kept in a different container. Apple cubes were separated into five containers as listed in Table 4 below:

Table 4 shows the categories of apple cubes in each container

Categories of Apple Cubes In Each Container
1. Uncoated 2. Coated without the turmeric oil 3. Coated with the turmeric oil (5μL) 4. Coated with the turmeric oil (10μL) 5. Coated with the turmeric oil (15μL)

In addition, in day 1, a reading of an untreated apple cube was taken and the reading was considered as the controlled value and the results of apple cubes that were treated will be compared with the value of the controlled value to monitor the effect of the treated apple cubes.

As the apple cubes were being observed for a few days, the apple cubes underwent the color changes as there were increased in a* and b* values and decrease in L* value. According to Perez-Gago et al. (2006), an increase in colorimetric a* and b* values and decrease in L* value (represent lightness), indicate that the enzymatic browning in the apple cubes were also increased. The lower the value of L*, the higher the loss of the lightness of the apple cubes.

Table 5 shows the value of L*a*b* reading for different turmeric oil concentration on their 6th and 12th day

	Control	Uncoated		Without TO		TO = 5μL		TO = 10μL		TO = 15μL	
Day		6	12	6	12	6	12	6	12	6	12
L*	77.38	66.01	54.70	69.24	54.78	72.83	67.91	74.13	70.92	75.53	72.01
a*	-1.80	2.17	4.72	3.64	4.95	2.28	3.17	2.07	2.63	1.05	1.33
b*	19.15	26.11	33.94	36.45	34.25	31.91	34.92	29.03	32.93	30.28	32.30
ΔE		13.91	27.85	19.88	28.01	14.15	19.05	11.10	15.85	11.64	14.54

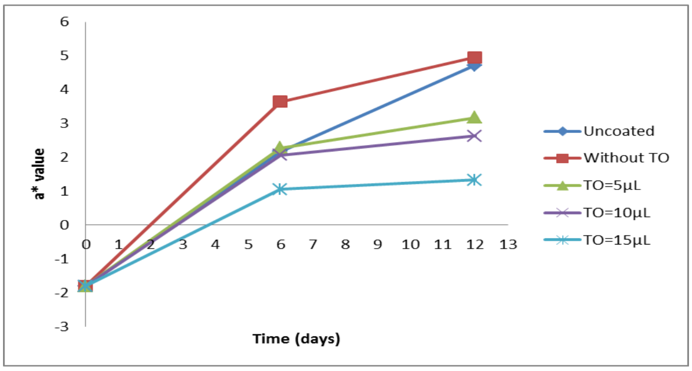


Figure 7: a* value of apple cubes during storage at 4℃ in the chiller

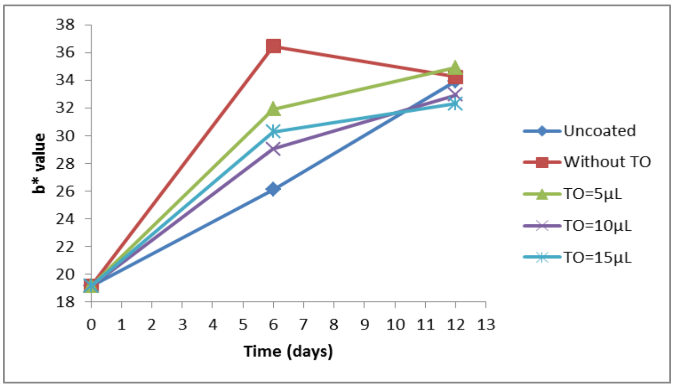


Figure 8: b* value of apple cubes during storage at 4℃ in the chiller

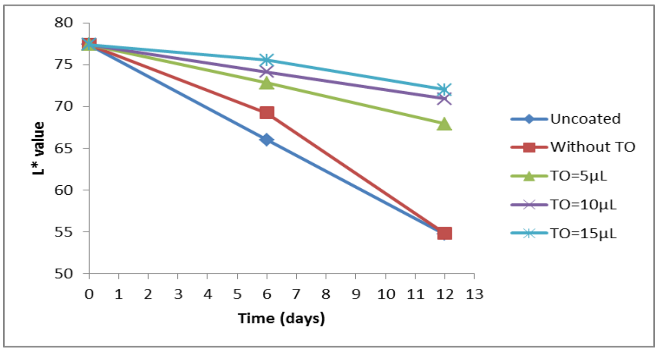


Figure 9: L* value of apple cubes during storage at 4℃ in the chiller

Table 5 shows the result obtained for the value of L*, a* and b* for apple cubes with different turmeric oil concentrations on their sixth day and twelfth day of storage. Meanwhile, Figure 7, 8 and 9 shows the result being plotted into the graph. From Figure 7, it can be seen that the value of a* seems to be increasing from the control value for all apple cubes in their sixth and twelfth day. However, after being observed, the value appeared to start slowing down on their increment with the apple cubes being coated with a solution that contain $5\mu L$ of turmeric oil. The value of a* further slowing down with higher concentration of turmeric oil. The same trend can also be implied with b* values as shown in Figure 8. An increase in a* and b* values indicates an increase in overall pigmentation of the apple cubes. However, the pigmentation starts to slow down with the usage of turmeric oil.

At the same time, the value of L* also further proving that the usage of turmeric oil can slow down the enzymatic browning of the apple cubes and also act as an antioxidant agent. In Figure 9, the value of L* seems to be decreasing from its control value. L* value in the CIE L*a*b* coordinated represent the lightness of an item and decrease in L* value indicate the loss of lightness. In this research project, the lower the L* value of the apple cubes means the higher the changes in color happened towards the apple cubes. Hence, the higher the rate of enzymatic browning of the apple cubes. In Figure 9, apple cubes that were uncoated and coated without the turmeric oil are showing the most drastic decrease in their L* value. Meanwhile, the apple cubes that are being coated with the turmeric oil but with different concentration are only showing a little decrease in their L* value. This also proved that the use of turmeric oil in coating the fresh cut fruits can help them decrease the rate of the enzymatic browning.

To further verifying that turmeric oil can act as an antioxidation agent by slowing down the rate of the enzymatic browning, the total color difference (ΔE) were calculated. By calculating the total color difference, it will be a good indicator of color change during the storage. Figure 10 below shows the result being plotted to a graph.

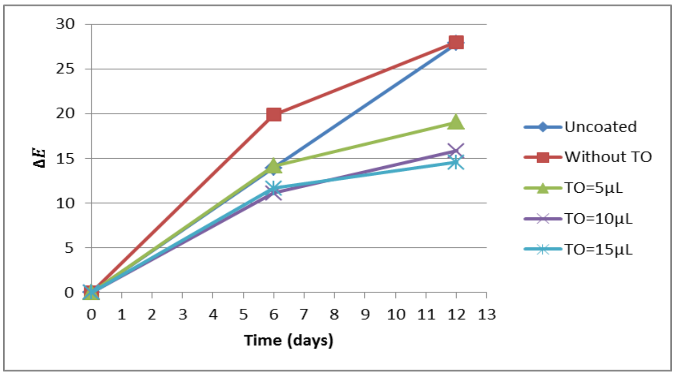


Figure 10: Total color difference (ΔE) for the apple cubes with different turmeric oil concentration during storage at 4℃ in the chiller

As being shown in Figure 10, the total color difference for the apple cubes increased significantly between day 0 and 6 of storage. However, for the apple cubes that were coated with the turmeric oil, the color difference seems to be remained approximately constant thereafter. But, apple cubes that were uncoated and coated without the turmeric oil continue to increase their color difference on their twelfth day of storage. The increases in the total color difference suggest an increase in the proportion of oxidized phenols during the storage. This further proving the characteristics of turmeric oil as antioxidation agent by slowing down the enzymatic browning reaction of the apple cubes.

E. Degree of Oxidation

Table 6 shows the value of absorbance at 420nm during storage at 4℃ in the chiller

Day	Uncoated	Without TO	TO = $5\mu L$	TO = $10\mu L$	TO = $15\mu L$
4	2.9606	2.9339	2.6242	1.9789	1.4300
8	3.2251	3.3048	2.7694	2.1552	1.5069
12	3.6001	3.5984	2.9537	2.3511	1.7082

The changes in absorbance at 420nm were studied with the time of treatment and also with the type of different coating for apple cubes. Significant differences for the degree of oxidation were observed among the apple cubes as shown in Table 6 and Figure 11. Results showed that increasing processing time also increase the absorbance at 420nm. However, that was not the only factor since it can be seen from Figure 11 that different type of coating also affected the absorbance rate at 420nm. Apple cubes that were uncoated and coated without the turmeric oil were leading the degree of oxidation followed by coating that contains $5\mu L$, $10\mu L$ and $15\mu L$ of turmeric oil respectively.

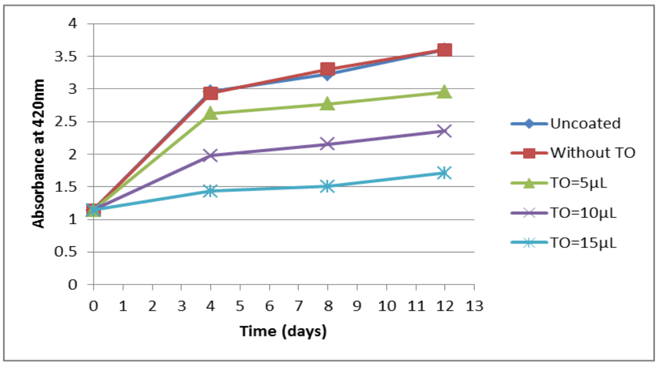


Figure 11: Change in the degree of oxidation at absorbance at 420nm during storage at 4℃chiller

As stated before, the degree of oxidation was monitored during cold storage in order to observe relationships with total phenolic or PPO activity. At zero time measurement of the change in absorbance at 420nm, the PPO activity already registered an initial reading at 1.1413. Similar to what was reported by Podsedek et al. (2000) regarding apple, the result for PPO activity of the apple cubes varied for the next fourth, eight and twelfth day of storage. Apple cubes that are coated with coating contained turmeric oil showed very little change during the storage especially apple cubes that coated with high concentration of turmeric oil. As for the apple cubes that were uncoated and coated without the turmeric oil, there were an enormous increased in their degree of oxidation on the fourth day of storage and it keeps on increasing till the twelfth day of storage.

After comparing the degree of oxidation of the apple cubes with five different type of coating, there was a correlation between the degree of oxidation and PPO activity or total phenolic with the type of the coating used. Apple cubes that were uncoated showed a very high degree of oxidation and it implies that the rate of enzymatic browning for the apple cubes that were uncoated is very high. However, for the apple cubes that were coated with coating contained $15\mu L$ turmeric oil, it only shows a slight increase from the initial reading and it proves that turmeric oil can preserve the apple cubes from the enzymatic browning. Also, the higher the concentration of turmeric oil used in a coating solution, the lower the rate of the enzymatic browning.

IV. CONCLUSION

Based on the findings, it can be conclude that turmeric oil has been showing its antioxidant characteristics for the fresh cut fruit that was used in this research which was an apple. All the apple cubes were stored inside a plastic container at a chiller with a temperature of 4℃. Apple cubes were divided into categories which were uncoated, coated without turmeric oil and coated with turmeric oil with three different concentrations which were 5μL, 10μL and 15μL respectively. Sensory evaluation has been done and within ten sensory panelist, 6 panelist rate the appearance and the surface color at a very good rate. Meanwhile for the weight loss, the uncoated apple cubes showed the highest percentage of weight loss during the twelfth day of storage which is 11.85% whereas apple cubes that were coated with coating that contain 15μL of turmeric oil showed the lowest percentage of weight loss which is 3.95%. This proved that the turmeric oil can help in reducing the moisture loss of the apple cubes and preserved it. Same goes for the color measurement where the apple cubes that were coated with coating that contain 15μL of turmeric oil showed the lowest total color difference which is ΔE = 14.54 at the twelfth day of storage. As for the degree of oxidation, the oxidation activity was measured at absorbance at 420nm and the results showed that increasing usage of turmeric oil decrease the absorbance at 420nm. Thus, it can be said that the turmeric oil can reduce the enzymatic browning from happening. In conclusion, turmeric oil has been showing its antioxidant activities for the fresh cut fruits which is an apple throughout this entire research and therefore the objectives for this research have been achieved.

ACKNOWLEDGMENT

Thank you to my supervisor, PM Dr Junaidah Jai, my co-supervisor, Miss Zatul Iranati binti Md. Sharif and Universiti Teknologi Mara.

REFERENCES

Ackbarali D.S., Maharaj, R. (2014). Sensory Evaluation as a Tool in etermining Acceptability of Innovative Products Developed by Undergraduate Students in Food Science and Technology at The University of Trinidad and Tobago. *Journal of Curriculum and Teaching* , 10-27.

Barrett, D.M., Beaulieu, J. C., Shewfelt, R. (2010). Color, Flavor, Texture, and Nutritional Quality of Fresh-Cut Fruits and Vegetables: Desirable Levels, Instrumental and Sensory Measurement, and the Effects of Processing. *Critical Reviews in Food Science and Nutrition*, 50:369-389.

Bengmark, S., Mesa, M. D., Gil, A. (2009). Plant-derived health: The effects of turmeric and curcuminoids. *Nutr. Hosp*. 24:273–281.

Chandra, A., Prajapati, S., Garg, S.K., Rathore, A.K. (2016). Extraction of Turmeric Oil by Continuous Water Circulation Distillation. *International Journal of Scientific Engineering and Applied Science* , 404-410.

Das, K. (2016). Turmeric (Curcuma longa) Oils. In V. Preedy, *Essential Oils in Food Preservation, Flavor and Safety* (pp. 835-841). London, UK: Elsevier.

Embuscado, M. (2015). Spices and herbs: Natural sources of antioxidants – a mini review. *Journal of Functional Foods*, 1-9.

Galeazzi, M. A. M., Sgarbieri, V. C. J. (1981). Substrate specificity and inhibition of polyphenoloxidase from a dwarf variety of banana. *Journal of Food Science*, 14014-1406.

Gonzalez-Aguilar, G.A., Ayala-Zavala, J.F., Olivas, G.I., De la Rosa, L.A., Alvarez-Parrilla, E. (2010). Preserving quality of fresh-cut products using safe technologies. *Journal für Verbraucherschutz und Lebensmittelsicherheit*, 65-72.

Hassan, Z. H., Lesmayati, S., Qomariah, R., Hasbianto, A. (2014). Effects of wax coating applications and storage temperatures on the quality of tangerine citrus (Citrus reticulata) var. Siam Banjar. *International Food Research Journal*, 641-648.

HunterLab (1995). Colorimeters vs. spectrophotometers. Applications note. Insight on Color, 5:6, 2 pp.

HunterLab (1996). Hunter lab color scale. Applications note. Insight on Color, 8:94 pp.

Jang, J.H., Moon, K.D. (2011). Inhibition of polyphenol oxidase and peroxidase activities on fresh–cut apple. *Food Chemistry*, 444-449.

Leggett, G. (2004). Tomato color measurement. Presentation at University of California – Davis, December 9, 2004.

Lindley, M. (1998). The impact of food processing on antioxidants in vegetable oils,. *Trends in Food Science & Technology*, 336-340.

Maria, A.R., Robert, S., Olga, M. (2009). Edible coatings to incorporate active ingredients to fresh-cut fruits: a review. *Trends in Food Science & Technology*, 438-447.

Martin, R. C., Aiyer, H. S., Malik, D., Li, Y. (2011). Effect on pro inflammatory and antioxidant genes and bioavailable distribution of whole turmeric vs curcumin: Similar root but different effects. *Food and Chemical Toxicology*, 50, 227-231.

Oriani, V.B., Molina, G., Chiumarelli, M., Pastore, G.M., Hubinge, M.D. (2014). Properties of Cassava Starch-Based Edible Coating Containing Essential Oils. *Journal of Food Science*, 189-194.

Ozoglu, H., Bayindirli, A. (2002). Inhibition of enzymatic browning in cloudy apple juice with selected antibrowning agents. *Food Control*, 213-221.

Perez-Gago, M.B., Serra, M., del R´ıo, M.A., 2006, Color change of fresh-cut apples coated with whey protein concentrate-based edible coatings. *Postharvest Biology and Technology*, Vol. 39, p. 84–92.

Podsedek, A., Wilska-Jeszka, J., Anders, B., Markowiski, J. (2000). Compositional characterisation of some apple varieties. *Eur. Food Res. Technol.*, 210, 268-272.

Queiroza, C., Lopes, M.L.M., Fialho, E., Valente-Mesquita, V.L. (2008). Polyphenol Oxidase: Characteristics and Mechanisms of Browning Control. *Food Reviews International*, 361-375.

Raghav, P.K., Agarwal, N., Saini, M. (2016). Edible Coating of Fruits and Vegetables: A Review. *International Journal of Scientific Research and Modern Education*, 188-204.

Rocha, A.M.C.N., Morais, A.M.M.B. (2001). Characterization of polyphenoloxidase (PPO) extracted from Jonagored apple.

Seiiedlou, S., Ghasemzade Hamid, R., Talati, F., Moghaddam, M. (2010). Convection Drying of Apple: Mathematical Modeling and Determination of some Quality parameters. *International Journal of Agriculture & Biology*.

Shahnawaz, M., Wali, A., Abbass S. (2013). A Study on the Shelf Life of Minimally Processed Apple with Edible Coatings. *Chemistry Journal*, 20-22.

Shariatifar, M., Jafarpour, E. (2013). Edible Coating Effects on Storage Life and Quality of Apple. *Journal of Basic and Applied Scientific Research*, 24-27.

Singh, G., Kapoor, I. P. S., Singh, P., Heluani, C. S., Lampasona, M. P., Catalan, C. A. N. (2010). Comparative study of chemical composition and antioxidant activity of fresh and dry rhizomes of turmeric (Curcuma longa Linn). *Food and Chemical Toxicology*, 48 (2010), pp. 1026-1031

Tzortzakis, N. G. (2007). Maintaining posthavest quality of fresh produce with volatile compounds. *Innovative Food Science Emerging Technologies*, 111-116.

Vander-Beng, L. (1981). The role of humidity, temperature and atmospheric composition in maintaining vegetable quality during storage. ACS Symp. Ser. 170: 95.

Voltaire, S., Poliana, D. G., Ligia, D. F. M., Isabel, C. T. (2013). Tracking bioactive compounds with colour changes in foods – A review. Dyes and Pigments, 601-608.

Watada, A.E, Qi, L. (1999). Quality of fresh-cut produce. *Postharvest Biol. Technol*., 201-205.