Effect of Chitosan-Based Edible Coating on Chemical and Physical Properties and Quality of Fruit

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***Abstract*— Foodborne outbreaks, precocious decaying and economic losses were common problems related to fresh fruit retention. These problems have led to the advance of novel technologies and systems for food protection such as edible coating based on natural compounds. In this study, an edible coating has been applied on the surface of fruits to lengthen its shelf-life. Other than that, it also offers protection against bacterial infection that leads to fruits spoilage by suppressing respiration, transpiration, and microbial growth. Latest studies have indicated chitosan as an effective coating that prolongs shelf-life and improves a storability of fresh fruit. Few characteristics possess by chitosan which makes it an excellent coating are high antimicrobial activity, biodegradability and non-toxic. The chitosan coating is also incorporated with turmeric essential oil as innovation based on the possible incorporation of the bioactive ingredient. The synergy between these two components may be useful to avoid a chain of biochemical and nutritional changes that could lead to fruits spoilage. The objectives of this study were to determine the effectiveness of chitosan-based edible coating in prolonging the quality of fruit and the effect of chitosan-based edible coating on chemical and physical properties of strawberry fruit from the chitosan-based formulation chosen. Fruits were dipped for 60 seconds in chitosan solution incorporated with turmeric essential oil. Non-treated fruits served as a control treatment. Samples were stored at room temperature up to 5 to 7 days. Quality analysis is performed every 2 days. The analysis included measurements of visual decay infection, structural analysis of chitosan-based solution, vitamin C determination and total soluble solid content (TSS). The results show that chitosan solution incorporated with turmeric essential oil could successfully improve shelf-life stability and retard postharvest deterioration of strawberries.**

Keywords—chitosan, edible coating, strawberry, shelf-life, turmeric essential oil

I. INTRODUCTION

Fragaria × *ananassa* or commonly known as strawberry is a herbaceous perennial plant in the *Rosaceae* (rose family); a hybrid cultivar of two wild *Fragaria* species found predominantly in semitropical regions worldwide especially in western South America; Florida and California. *Fragaria* × *ananassa* is only one part in the strawberry species, with *virginiana*, *chiloensis* and *vesca* are the few names of the species. The fruit is famous for its colour, flavour and fragrance. Hence, its characteristic is widely cherished and used in lots of industries such as food and cosmetics.

Strawberries contain a good deal of vitamin C, which is helpful for the development of strong connective tissues and provides protection to the immune system from attacks of various pathogenic microorganisms. It could also prevent infections or microorganism in the liver, bladder, or kidney; inflammation; or cancer from the bioactive compounds in the phytochemicals. The bioactive compounds from Strawberries could block the entry of microorganism from adhering to the human cells that line the walls of the liver, kidneys or urinary tract (Kellogg, et al., 2010). Other than that, the pigments may be responsible for their blue and red hue. The strawberries’ fruits and leaves can be used to relieve sore mouths, soothes sore throats, nausea, aphtha, stomatitis, diabetes, diarrhoea, cancer, inflammation, and dysentery (Schieber, Stintzing, & Carle, 2010).

Edible packaging is a film or coating formed on foods. For centuries, edible films and coatings such as wax have been applied on numerous fruits to deter moisture loss and to create a shiny fruit surface for appealing purposes. The packaging is developed to be biodegradable so it can degenerate in a reasonable amount of time. The advantages of the packaging other than its edibility are its barrier to gas properties, nontoxicity, and non-polluting, and low cost. Other than that, the packaging act as antioxidants in food additives and are used widely, on the whole in food preservations (Pavlath & Orts, 2009)

External and internal qualities are vital to consumer acceptability and marketing consideration. Consequently, the edible packaging needed for preserving the quality attributes of a variety of food during handling, distribution and retail sale. Today, edible films uses have expanded promptly worldwide and have been improving economic efficiency in food markets regarding quality and its shelf-life (Chien, Sheu, & Yang, 2007).

Chitosan is one of the biomaterials developed particularly for food and packaging applications. It is a linear polysaccharide consisting of β-(1→4)-linked 2-amino-2-deoxy-D-glucose residues, originating from deacetylate derivative of chitin, which is the second most abundant polysaccharide in nature after cellulose. It could effectively control food decay as it has strong antimicrobial and antifungal activities. Chitosan coating can reduce the respiration rate of food by controlling its gas permeability.

Chitosan is combined with other compounds to enhance its antimicrobial activity. The mixture of chitosan with essential oils have been demonstrated in other research to enhance the antimicrobial effect and may represent a real alternative to the

use of synthetic fungicides such as thiabendazole (Samuel P Davis, 2011).

II. METHODOLOGY

A. Material

Strawberries were purchased in a local supermarket, Shah Alam, Selangor. All fruits were selected based on the same ripening stage, uniform size, the absence of any physical damage and fungal infection.

B. Preparation of tapioca starch solution

Tapioca starch solution was prepared by dissolving 4 g of tapioca starch powder in 100 ml of distilled water for 40 minutes at 80 ^{o}C. Then, 2 ml of glycerol was added to the solution.

C. Preparation of chitosan solution

Chitosan solution was prepared by dissolving 1 g of chitosan in a dilution of 0.5% v/v of acetic acid by using 100 ml distilled water with continuous stirring at room temperature. After the complete dissolution of the chitosan, 2 ml of glycerol and 0.1 ml of Tween80 were added and the solution was stirred for 24 hours. Afterwards, the pH of chitosan solutions was adjusted by titration with 0.1 M NaOH until a pH of 5.6 is reached.

D. Preparation of chitosan, starch and turmeric oil solution

A 100 ml of prepared chitosan solution was continuously stirred at room temperature. 1 ml of prepared starch was added into the chitosan solution. The prepared solution was continuously stirred and 5 mL of turmeric essential oil was added. The process was repeated using a different concentration of 5 mL, 10 mL and 20 mL of turmeric oil for every 100 ml prepared chitosan solution and 1 ml starch solution.

Table 1: Coding and type of coating of the strawberries

Sample code	Sample treatment	
	Type of sample	Type of coating
A	Control	None
B	Coated	Chitosan, starch
C	Coated	Chitosan, starch, 5 mL TO
D	Coated	Chitosan, starch, 10 mL TO
E	Coated	Chitosan, starch, 20 mL TO

E. Sample preparation

Strawberries of uniform size and colour, weighing around 10 g were prepared. The strawberries were dipped into the different concentration of turmeric oil of chitosan solution for 1 minute. The excess coating materials were allowed to drain and dry on a tray.

F. Appearance determination

The strawberries were examined for mold during storage. The fruits were visually inspected for any signs of mycelia development on the fruit surface. Infected strawberries were characterised as moldy, with brown spots and softening of the infected area. The results were expressed as the percentage of infected fruit depending on its area infected.

G. Chemical structural analysis of chitosan solution determination

The chemical structure of chitosan solution analysis was recorded by FTIR (Perkin Elmer Spectrum One) apparatus. No specific preparation was required for the analysis.

H. Vitamin C determination

The concentration of vitamin C in strawberry was determined by a spectrophotometric method. Ten grams of strawberry was homogenised in about 100 ml of 4% w/w $H_2C_2O_4$ solution. The mixture was filtered in order to separate the solid residue from the liquid. The liquid was then diluted to a certain volume with $H_2C_2O_4$. For calibration process, the standard solutions were prepared from 100 $\mu g.ml^{-1}$ ascorbic acid solution in a certain volume of 4% w/w $H_2C_2O_4$ was added with 1 ml of 50 $\mu g.ml^{-1}$ $CuSO_4.5H_2O$ solution. The absorbance values were recorded as 288 nm.

I. Total soluble solid content (TSS)

The 10 g strawberries were cut into small pieces and homogenised for 1 minute using a slow juicer and then filtered. The SSC was determined in the juice of blended strawberries by means of an AR2008 Series Abbe Refractometer and expressed as a percentage.

III. RESULTS AND DISCUSSIONS

A. Appearance determination

Since strawberries are known to be highly perishable fruits, their shelf life was defined as the time elapsed between the coating application and the appearance of fungal infection. The signs of strawberry infection in the control strawberry (A) appeared only after 3 days of storage. The coated strawberries, on the other hand, exhibited delayed mycelia growth as shown in Figure 4.

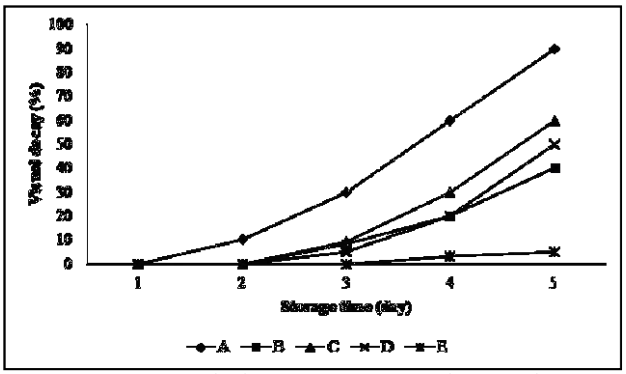

Figure 1: Percentage of infected strawberries as a function of storage time (day)

The strawberries were examined for mold during storage. Fruits from all groups were visually inspected for any signs of mycelia development on the fruit surface. Infected strawberries were characterised as moldy, with brown spots and softening of the infected area. The results were expressed as the percentage of infected fruit as seen in Figure 1. Mold infection in the coated strawberries was noticeable after 4 days of storage. On the fifth day, 90% of control fruit (A) were infected. The mold infection incidence of the chitosan coated fruit (B), fruit (C) and fruit (E) was around 60 to 40% respectively, while the infection of fruit (E) was less than 10%.

These results agree with findings of (Kalaycıoğlu, Torlak, Akın-Evingür, Özen, & Erim, 2017), who reported that the turmeric incorporated chitosan films exhibit the antibacterial activity. Thereby, turmeric extract incorporated chitosan films can be suggested as potent coating agents with improved film properties and antimicrobial activities against food pathogens. Moreover, it was proven that the findings provided a new level of understanding on the antifungal behaviour of turmeric essential oil. Most importantly, its highly antifungal efficiency evidenced that turmeric essential oil could become a promisingly economical antifungal agent in practice (Hu, Zhang, Kong, Zhao, & Yang, 2017).

B. Chemical structural analysis of chitosan solution determination

FTIR analysis was used to observe the effect of TO incorporation on the chitosan solutions. Figure 2 presents the FTIR spectrum of the CH powder, STA solution, TO, CH-STA solution, CH-STA with 5 mL TO solution, CH-STA with 10 mL TO solution, and CH-STA with 20 mL TO solution.

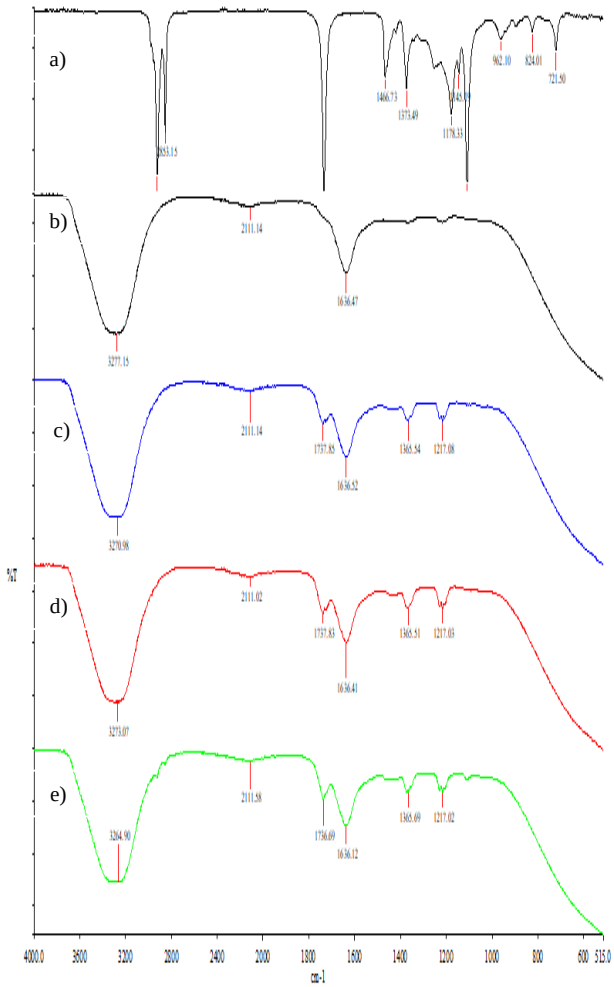

Figure 2: FTIR spectrum of chitosan-based coating solutions with turmeric essential oil; a) TO, b) CH-STA solution, c) CH-STA with 5 mL TO solution, d) CH-STA with 10 mL TO solution, e) CH-STA with 20 mL TO solution

Shen & Kamdem stated that FTIR spectra showed similar general features, with most of the peaks characteristic of CH films which explain the insignificant difference in spectra for all coating solutions. A list of the functional group presents in the edible based coating in Figure 2 is tabulated in Table 2 below:

A broad absorption band at the range of 3265 and 3278 cm^{-1} due to over-lapping of a hydroxyl group, O-H and amino group, NH_2 stretching was observed in all coating solutions (Liu, Cai, Jiang, Wu, & Le, 2016). The peaks at the range 2112 cm^{-1} correspond to the -C≡C- stretch as a weak band from 2100-2260 cm^{-1}. The peaks at the range 1737 cm^{-1} was attributed to the C=O stretch (1670-1820 cm^{-1}). The peaks at the range 1366 cm^{-1} were attributed to bending of –C-H (1350-1480 cm^{-1}) and the peaks of the range 1217 cm^{-1} correspond to C-O stretching (1210-1320 cm^{-1}).

As seen from the spectra, typical peaks have shifted in coating solutions in Figure 2b, c, d and e shows the functional groups inside the turmeric oil aside from other materials were presence in the coating solution. The presence of these functional group is sufficient to make an an excellent edible coating to stop microbial activity in fruit. A similar observations with the addition of turmeric extract into the chitosan film is consistent with the study. (Liu, Cai, Jiang, Wu, & Le, 2016).

Table 2: Type of functional group present in the edible based coating solution (Robert M Silverstein, 2005)

Functional Group	Type of Vibration	Characteristics Absorption (cm^{-1})
Alkane		
C-H	Stretch	2850-3000
-C-H	Bending	1350-1480
Alkene		
C=C	Stretch	1620-1680
Alkyne		
-C≡C-	Stretch	2100-2260
Amine		
N-H	Stretch	3300-3500
Acid		
C=O	Stretch	1670-1820
C-O	Stretch	1210-1320
Aromatic		
C=C	Stretch	1400-1600
Ether		
C-O	Stretch	1000-1300

C. Vitamin C determination

The total ascorbic acid content of strawberries was evaluated in order to study the barrier properties of chitosan to oxygen permeability. The effect of coating on the reduction of total ascorbic acid after seven days of storage was tabulated in Table 3 and presented in Figure 3

Table 3: Total ascorbic acid

Sample	Type of sample	Total Ascorbic Acid (mg 100 g^{-1})			
		Day 1	Day 3	Day 5	Day 7
A	Control	2.0177	1.9626	1.2048	0.4908
B	Coated	2.2366	2.6383	1.6478	0.6021
C	Coated	2.2518	2.2924	1.9431	0.6696
D	Coated	2.0655	2.4318	1.9208	0.6904
E	Coated	2.2518	2.3279	2.301	0.7328

Application of chitosan-based edible coatings in combination with TO gives a substantial effect on the ascorbic acid content of the strawberries. There was a decrease in the contents of ascorbic acid in both coated and control fruit with the storage time and the coating treatment significantly inhibited the decrease.

The initial ascorbic acid content of strawberry fruit was 2.0177 mg 100 g^{-1}. After 7 days of storage, the uncoated samples showed considerably lower amounts of ascorbic acid which was 0.4908 mg 100 g^{-1}, while the edible coatings caused a delay in the decrease of the ascorbic acid content. The amount of ascorbic acid on the last day of storage of coated fruit were 0.6021, 0.6696, 0.6904, 0.7328 mg 100 g^{-1} for coated fruit B, C, D, and E respectively.

Gol, Patel, & Rao (2013) reported that the incorporation of chitosan to coating formulations may reduce O_2 diffusion, slowing down the respiration rate, which delays the deteriorative oxidation reaction of an ascorbic acid of fruit (Sogvar, Koukesh Saba, & Emamifar, 2016).

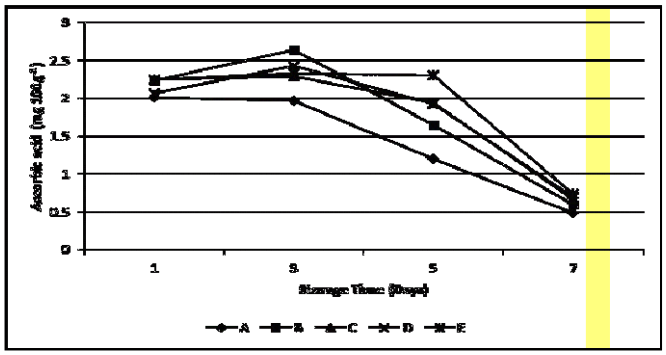

Figure 3: Effect of coating treatment to the total ascorbic acid

D.Total soluble solid content (TSS)

One of the important parameters that affect the fruit quality and consumer acceptability was TSS (Aday & Caner, 2013). The results are tabulated such as in Table 4 and were analysed and presented in Figure 5.

The result of coated treatment on TSS of strawberry fruit was possibly due to the suppression of respiration rate and metabolic activity, such as the conversion of sugars into CO_2 and H_2O or the hydrolysis of cell wall polysaccharides (Petriccione, et al., 2015).

Storage Time (Day)	Coating Sample				
	A	B	C	D	E
1					
2					
3					
4					
5					

Figure 4: Fruit visual infection

Table 4: Total soluble solids content

Sample	Type of sample	Brix value (%)			
		Day 1	Day 3	Day 5	Day 7
A	Control	3.2	3.6	3.9	4.5
B	Coated	3.2	3.5	3.8	4.3
C	Coated	3.2	3.4	3.7	3.9
D	Coated	3.2	3.3	3.5	3.7
E	Coated	3.2	3.3	3.4	3.6

The increase in TSS during storage can be explained by the fact that hydrolysis of sucrose to maintain metabolic activity was more rapid in sample (A) compared with coated fruits (B – E) (Aday & Caner, 2013). There was a significant difference in the TSS values of coated samples (B - E) compared to the uncoated sample (A) at the end of the storage. It was possible that the high sugar content in the sample (A) caused higher TSS content.

A study also documented that the property of chitosan results in modification of the internal atmosphere by reducing O_2 and elevating CO_2, and suppressing ethylene evolution hence, retarding the ripening process (Gol, Patel, & Rao, 2013)

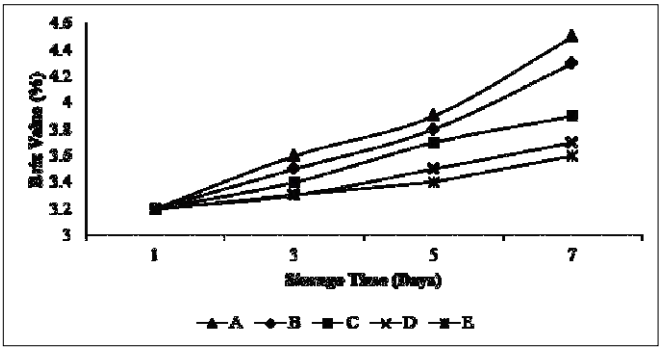

Figure 5: Effect of different coating materials on TSS values of strawberry

IV.CONCLUSION

The results of the present study asserted that the incorporation of TO into chitosan improved its chemical and physical properties and also the quality of fruit. Chitosan with 20 mL TO has proven to be an effective coating that prolongs the shelf-life and improves a storability of fresh fruit. The used of chitosan with 20 ml TO has enhanced the chemical structure

of chitosan as determined by FTIR. The coating also improves the aesthetic appearance and decrease the decay of the fruit, Other than that, the coating reduces the TSS content and slows down the ascorbic acid content with time which makes it an excellent coating for reducing microbial activity, as it is biodegradable and non-toxic. In conclusion, addition of turmeric oil to coating solution enhanced the chemical and properties other than improving its quality by prolonged the microbial activity in fruit consequently, applying the coatings with chitosan and turmeric oil to strawberry fruit may improve its commercial demand in the market. And so, the objectives of the research have been attained.

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