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Research paper

Effect of Turmeric Oil in Chitosan-Based Edible Coating on Physical and Chemical Properties of Strawberry

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Abstract

Foodborne outbreaks, precocious decaying and economic losses are 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 source materials. In this study, a chitosan based edible coating had been applied on the surface of strawberry to lengthen its shelf-life. It also offers protection against bacterial infection that leads to strawberry spoilage by supressing respiration, transpiration and microbial growth. Turmeric essential oil was added in the chitosan coating as innovation based on the possible synergy effect of these two components to improve the storability of strawberries after postharvest which is a crucial point for import-export of fresh fruits. The objective of this study was to determine the effect of chitosan-based edible coating with turmeric essential oil as bioactive ingredient on chemical and physical properties of strawberry. The chitosan-based edible coating was added with different concentrations of turmeric oil 0%, 5%, 10% and 20% while uncoated strawberry was named as control. Visual decay infection, structural analysis of chitosan-based solution, vitamin C determination and total soluble solid content (TSS) were then investigated. The results indicated that coated strawberry with presence of turmeric oil were able to maintain the studied chemical and physical properties of strawberries during 7 days of storage more efficiently than control and 0% concentration of turmeric oil. Study also found that the strawberry that contains highest concentration of turmeric oil at 20% had the lowest percentage of visual decay (<10%), the lowest total soluble solid solid content (3.6%) and the highest content of ascorbic acid (0.73 mg100g^{-1}). Therefore, the synergy between chitosan-based edible coating with turmeric oil successfully improved the longevity shelf-life by extending the postharvest deterioration of strawberries.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

Fragaria x ananassa or commonly known as strawberry is an herbaceous perennial plant in Rosaceae. Strawberry is not the seasonal fruits as it will growth through all the year. When it reached its maturity state, strawberry are harvested in large quantity and being preserved in suitable condition before being distributed to the consumer [1]. However, the quality of the strawberry will be affected during transportation and distribution due to the respiration process. In order to commercialize the strawberry, its quality and organoleptic properties should be retained until it reached the consumer hand. Thus, efficient preservative methods should be applied to prolong the shelf life of strawberry during storage and transportation process [2],[3].
There are various methods of preservation that can be applied to extend the strawberry shelf life. Currently, the used of edible coating film in maintaining the fruits organoleptic properties are getting wide attention. These are due to its properties that able to control the moisture transfer, respiration process and oxidation process [4]. Furthermore, the used of edible coating are safe to be consume by consumer as it is made up from natural based [5]. Commonly, edible coating film were made up of three types of hydrocolloids which are polysaccharides, proteins and lipids as its main bases [6]. Despite of using a type of hydrocolloid, the mixture of those three types hydrocolloids also can be used in producing the edible coating film and this edible coating film is known as composite edible coating film [7]. Besides that, edible coating had the ability to be used with the presence of food preservatives such as antimicrobial agent, antioxidation agent, and chelating agents [8]. In this research study, turmeric oil was used as the antimicrobial agent. Turmeric oil consists of secondary metabolites that can act as antimicrobial agent such as turmerone, Ar-turmerone, curlone, cumene and many others [9]. Additional of turmeric oil in the edible coating film could enhance more its function as to protect the strawberry from deteriorate that causes by microbial and fungus.
In this study, composite edible coating was used as the edible coating based which are the mixture of cassava starch and chitosan. Cassava starch is made up of amylose and amylopectin that are connected by hydrogen bond and formed the semi-crystalline granules naturally. Presence of water and heat could swelling and hydrating the granules which leads in increasing the viscosity of the solution [10]. Cassava starch has poor mechanical properties which it has brittle and fragile characteristic. Presence of chitosan could improve the edible coating of cassava starch based film due to its structural compatibility [11]. 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 [12]. Chitosan could modify the starch granule size six times larger compared to the original size. Besides that, the hydroxyl group that present in starch will interact with the amino groups that present in chitosan. Furthermore, this interaction could reduce the starch degradation [13]. The mechanical properties of this composite edible coating are improve more by adding plasticizer such as glycerol and sorbitol.
The objective of this research is to determine the effect of chitosan with turmeric essential oil as bioactive ingredient on chemical and physical properties of strawberry.

2. Materials and methods

The strawberries at commercial maturity with absence of any physcial damage and fungal infections were purchased in a local supermarket (Selangor, Malaysia) and stored in cold condition at 4 ± 2°C until used. Local commercial brand cassva starch (Brand Kapal ABC. Co) was used as the biopolymer for edible coating formulation. Food grade chitosan with 97% deacetlylation (Nacalai Tesque, Japan) was used as composite coating together with cassava starch and was dissolved in acetic acid (Friendemann Schmidt, Australia). Glycerol (Merck, Germany) was added as plasticizer for coating formulation. Turmeric essential oil (BF1 Sdn. Bhd., Malaysia) and Tween 80 (Systerm, Lab Sciences Engineering Sdn. Bhd., Malaysia) were used as antimicrobial agent sources and emulsifier, respectively. Sodium hydroxide (Sigma-Aldrich, United States) at concentration 0.1 M was added to control the pH of the formulations.

2.1 Preparation of edible coating solutions

Edible coating formulation was prepared by gelatinization of 4 g tapioca starch in 100 mL of distilled water at temperature 80°C under continuous stirring for 40 minutes. The gelatinized tapioca starch solution was then plasticized with glycerol at volume percentage of 2%.
Chitosan solution was prepared by dissolving 1 g of chitosan flakes in in a dilution of 100 mL 0.5% v/v of acetic acid at 25°C and continuously stirred until clear solution was formed. 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.
Afterward, the pH of chitosan solutions was adjusted by titration with 0.1 M NaOH until a pH of 5.6 was reached. The effect of turmeric oil content on the physical and chemical properties of the strawberries was studied by varying the volume of turmeric oil at 5 mL, 10 mL and 20 mL for every 100 mL prepared chitosan solution blended with 1 mL of gelatinized starch solution.

2.2 Coating application on strawberry

The strawberries were gently washed and dried prior to the coating process. The strawberries were dipped into different formulation of coating solutions except for the control sample for one minute and coded as listed in Table 1. The strawberries were placed on the tray and the coating solutions were allowed to dry at 25°C and stored in container prior the analysis. Physical and chemical analysis was performed on the 1, 3, 5 and 7 days of storage.

Table 1: Sample coding

Code	Edible coating formulations
A	Uncoated strawberry as control
B	Strawberry coated with Chitosan + Starch
C	Strawberry coated with Chitosan + Starch + 5 mL TO
D	Strawberry coated with Chitosan + Starch + 10 mL TO
E	Strawberry coated with Chitosan + Starch + 20 mL TO

2.3 Chemical structural analysis of edible coating formulation films

Fourier Transform Infrared (FTIR) analysis was used to study on the chemical structure of edible coating formulations of tapioca starch and chitosan with presence of different volume of turmeric oil. The sample port of FTIR (PerkinElmer) was cleaned by using acetone to remove any variation cause by contamination on the scanning prior to the sample analysis. The FTIR analysis were conducted at wavenumber range from 400 to 4000 cm^{-1}. The spectrums yield from the samples scanning were collected and studied.

2.4 Fungal decay

The strawberries were examined for fungal growth during storage at room temperature around 25+2°C using the method proposed by Valenzuela *et al.* [14]. The fruits were visually inspected for any signs of fungal growth on the fruit surface. Infected strawberries were characterized 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.

2.5 Vitamin C determination

The concentration of vitamin C (ascorbic acid) in strawberry was determined by a spectrophotometric method as proposed by Majidi and AlQubury [15] with modifications. The measurement was quantified by using Ultraviolet-Visible (PerkinElmer). Ten grams of strawberry was homogenized by 100 mL of 4% w/w $H_2C_2O_4$ (oxalic acid) solution. The mixture was filtered in order to separate the solid residue from the liquid. For calibration purposes, the standard solutions were prepared from 100 $\mu g.ml^{-1}$ ascorbic acid solution in a pre-determined volume of 4% w/w $H_2C_2O_4$. The solution was then added with 1 ml of 50 $\mu g.ml^{-1}$ $CuSO_4.5H_2O$ (Copper (ll) sulfate pentahydrate) solution for colored solution purpose. The absorbance values were recorded at 249 nm.

2.6 Total soluble solid content (TSS)

Total soluble solid (TSS) content measurement was done to identify the flavor and internal quality of the strawberries which are mainly related to soluble solids content mainly sugars. The method was carried out according to Magwaza and Opara [16] method. Ten grams strawberries were cut into small pieces and homogenized for 1 minute using a slow juicer and then filtered. The soluble solid content was determined in the juice of blended strawberries by means of an AR2008 Series Abbe Refractometer (Mettler Toledo) and reported as "degrees Brix" which was expressed as percentage (%).

3. Results and discussions

3.1 Chemical structural analysis of chitosan solution determination

The effects of chemical structural changes of starch-chitosan edible coatings after the addition of turmeric oil were studied using FTIR. Fig. 1 compares the FTIR spectrum of the chitosan powder, starch solution, turmeric oil, chitosan-starch solution (B), chitosan-starch solution with 5 mL turmeric oil (C), chitosan-starch solution with 10 mL turmeric oil (D) and chitosan-starch solution with 20 mL turmeric oil (E).
From Fig. 1 (a & b), it can be seen that chitosan powder and gelatinized starch solution respectively shows that both of the edible coating polymer based had O-H region (red line) at wavenumber about 3200cm^{-1}. It was expected that the crosslinking reaction of the polymeric chain to occurs at this region by formation of hydrogen bond. This is in agreement with study done by Ahmad *et al.* [17]. Referring to Fig. 1 (d-g), after the edible coating process, the general features of most FTIR characteristics peaks remains similar.

This indicates the uniformity of the biopolymers with presence of turmeric oil which explains the insignificant difference in spectra for all coating solutions.

A broad absorption band at the range of 3265 and 3289 cm^{-1} indicating the presence of hydroxyl, O-H group and peaks at 1737 cm^{-1} (purple line) attributed by the presence of C=O stretch were observed in all coating solutions. Both of this functional group indicated the presence of chitosan and tapioca starch in the edible coating formulations. Meanwhile, the peaks at the range 2112 cm^{-1} (blue line) corresponded to the -C≡C- stretch as a weak band also confirming the presence of tapioca starch. The functional group of the respective regions was justified accordingly to Liu *et al.* [18].

Addition of turmeric oil in edible coating formulations as shown in Fig. 1 e)-g) spectra shows the presence of three new succesive peaks at about 1750 cm^{-1}, 1400 cm^{-1} and 1200 cm^{-1} attributed by the presence of C=O stretch, O-H bend and aryl-O stretch. The assignments of the peaks were justified according to study done by Coates [19]. Besides that, it can also be seen that-C≡C- region and C=O stretch region peaks were shifted toward lower wavenumber. This may attribute by the intermolecular interaction of the polymeric chain with the turmeric oil at this region.

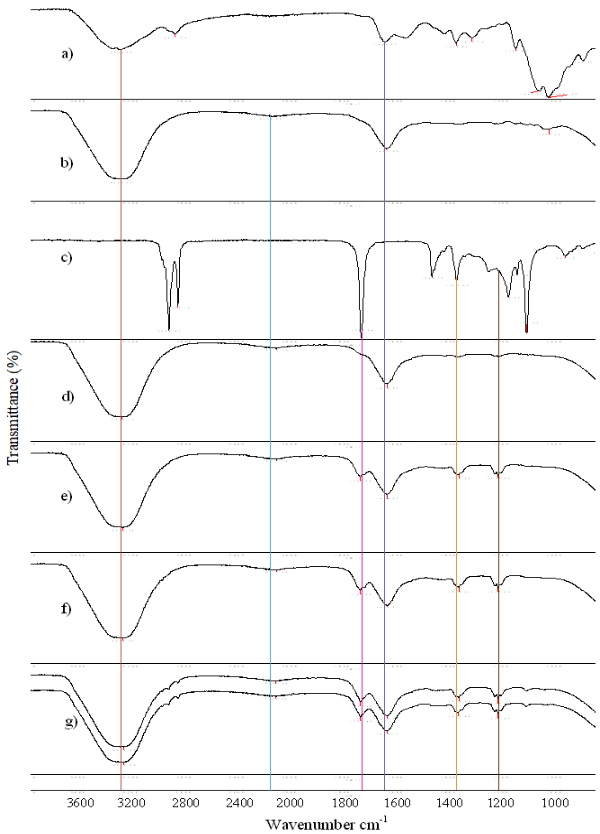

Fig. 1: FTIR spectrum of a) Chitosan powder, b) Starch solution, c) Turmeric Oil, d) chitosan-starch solution (B), e) chitosan-starch with 5 mL turmeric oil (C), f) chitosan-starch with 10 mL turmeric oil (D), g) chitosan-starch with 20 mL turmeric oil (E)

3.2 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 infections as shown in Fig. 2. Referring to Fig. 2, the signs of strawberry infection on the control strawberry (A) appeared after 3 days of storage. The coated strawberries without and with presence of turmeric oil, on the other hand exhibited delayed fungal growth in comparison with A. Mold infections in the coated strawberries B, C and D was noticeable after 3 days of storage while coated strawberry E after 4 days of storage. On the fifth day, 90% of control fruit (A) were infected. The mold infection incidence of the edible coated strawberry (B), (C) and (E) was around 60% to 40% while the infection of strawberry (E) was less than 10%. Study shows that the highest content of turmeric oil at 20 mL in chitosan-tapioca starch edible coating had the slowest rate of fungal growth.

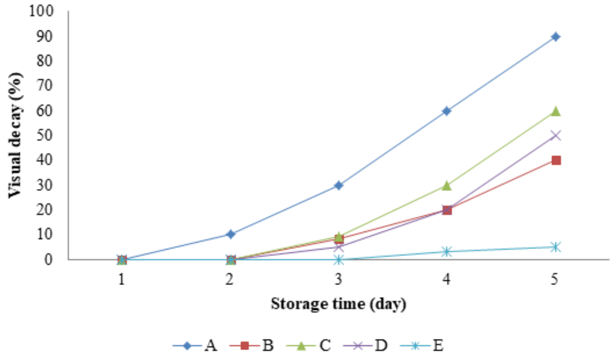

Fig. 2: Percentage of infected strawberries as a function of storage time (day)

This finding was supported by Kalaycıoğlu *et al*., [20], who reported that the turmeric incorporated chitosan films exhibit the antibacterial activity. Thereby, turmeric essential oil incorporated in tapioca starch-chitosan edible coating can be suggested as potential active edible coating with improved antimicrobial activities against food pathogens. Moreover, it is proven that the findings provided a new level of understanding on the antifungal behavior of turmeric essential oil. Most importantly, its highly antifungal efficiency evidenced that turmeric essential oil could become a promisingly economical antifungal agent in practice which also agreed by Hu *et al.* [21].

3.3 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 presented in Fig. 3. Application of chitosan-based edible coatings in combination with turmeric oil gives a substantial effect on the ascorbic acid content of the strawberries (Fig. 3). Generally, there is a decrease in the contents of ascorbic acid in both coated and control fruit with the storage time. However, strawberry with the coating treatment significantly reduced the decrease rate.

The initial ascorbic acid content of strawberry A was 2.0177 mg100 g^{-1} and after 7 days of storage, the uncoated samples showed considerably lower amounts of ascorbic acid which is 0.4908 mg100 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 are 0.6021, 0.6696, 0.6904, 0.7328 mg100 g^{-1} for coated fruit B, C, D, and E respectively. The highest content of ascorbic acid was found in strawberry E on the 7^{th} day. This may attributed by the synergy effect of chitosan and turmeric oil where both could act as antioxidation agent. Similar findings were found by Gol, Patel, & Rao [22] and Sogvar *et al.* [23]. Formulation of edible coating including chitosan and turmeric oil reduced O_2 diffusion which slowing down the respiration rate and thus defered the deteriorative oxidation reaction of ascorbic acid of fruits.

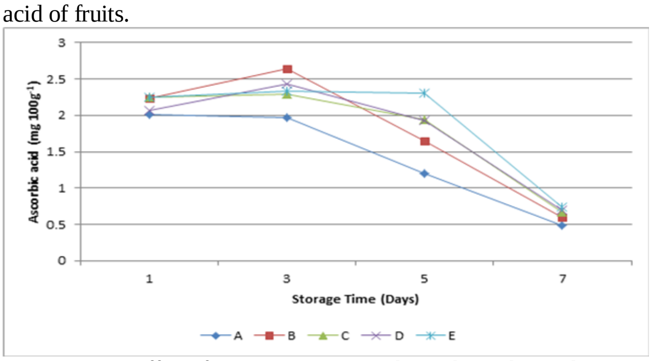

Fig. 3: Effect of coating treatment to the total ascorbic acid

3.4 Total soluble solid content (TSS)

Total soluble solid content (TSS) was conducted to quantitatively measure the internal quality of the strawberry. This is an important parameter for consumer acceptability as stated by Aday and Caner [24]. The results are presented in Fig. 4 where the value was expressed as Brix value (%). 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 as suggested by Petriccione *et al.*, [25].

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). Similar finding was found by Aday and Caner [24]. There was significant difference in the TSS values of coated samples (B - E) compared to the uncoated sample (A) at the end of the storage. It is possible that, the high sugar content in sample (A) caused higher TSS content.

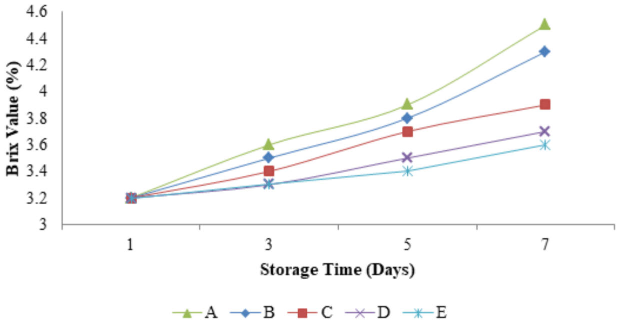

Fig. 4: Effect of different coating materials on TSS values of strawberry.

A study done by Gol *et al.*, [22] also documented that the property of chitosan results in modification of the internal atmosphere by reducing O_2 and/or elevating CO_2, and suppressing ethylene evolution hence, retarding the ripening process.

4. Conclusion

The results of the present study asserted that the incorporation of turmeric oil into chitosan improved its chemical and physical properties of the strawberries. Tapioca starch-chitosan edible coating with presence of 20 mL turmeric oil has proven to be an effective coating that prolongs the shelf-life and improves a storability of the fresh strawberry. The molecular interaction between the turmeric oil with the polymeric chain of the edible coating as shown in FTIR analysis proved that prevention of fruits spoilage was contributed by the synergy between these two materials. The coating also improves the aesthetic appearance and decrease the decay of the fruit. Other than that, the coating also 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 biodegradability and non-toxic. Therefore, applying the coatings of strawberry with chitosan and turmeric oil may improve its commercial demand in the market.

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