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RESEARCH ARTICLE

Application of Soy Protein Isolate Edible Coating for Mangosteen (*Garcinia Mangostana)* Storage

Nguyen Phuoc Minh[1*], Tran Thi Yen Nhi[2], Luong Tu Anh[3], Thach Thi Phuong Dung[4], Thach Thi Hien[5]

1. *Faculty of Chemical Engineering and Food Technology, Nguyen Tat Thanh University, Ho Chi Minh, Vietnam.*
2. *NTT Hi-Tech Institute, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam.*
3. *Cuu Long University, Bac Lieu Province, Vietnam.*
4. *An Giang University, Dong Thap Province, Vietnam.*
5. *Can Tho University, Can Tho City, Vietnam.*

***Corresponding Author:Nguyen Phuoc Minh**

Abstract

Recently, the mangosteen has been noted to be an abundant source of a class of polyphenols known as xanthones It has a variety of health promoting properties including anti-inflammatory, anti-oxidant, and anti-cancer activity. Mangosteen fruits have a storage and marketable postharvest life of not more than one week under tropical conditions. In order to have supply of this fruit between harvest seasons, which ranges from two to four months depending on local production, it is necessary to use postharvest techniques for the extension of mangosteen shelf life. Application of soy protein isolate as edible coating could be considered as a useful approach to maintain its product quality during preservation. Ojective of the present study focused on the effect of soy protein isolate coating on some physicochemical, microbial and sensory characteristics of mangosteen during preservation. Optimal results showed that weight loss, pH, total soluble solids, titratable acidity and ascorbic acid; total plate count; sensory characteristics could be maintained at appropriate levels by coating mangosteen with 1.5% soy protein isolate.

Keywords: *Mangosteen, Soy protein isolate, Coating, Preservation, Physicochemical, Microbial, Sensory.*

Introduction

The mangosteen (*Garcinia mangostana*) is a tropical fruit cultivated in the South of Vietnam and has long been reported to contain multiple health promoting properties. The pulp and seeds of G. mangostana afforded stigmasterol and triacylglycerols, while the pulp yielded a vitamin E, δ-tocotrienol and two xanthones, α-mangostin and 3-isomangostin with reported diverse biological activities [1].

This fruit is an abundant source of xanthones, a class of polyphenolic compounds with a distinctive tricyclic aromatic ring system and is largely responsible for its biological activities including anti-cancer activity [2]. The exocarp of the fruit is deep purple in color with a white pulp and typically contains 6–8 arils [3].

Functional beverage of *Garcinia mangostana* (mangosteen) enhances plasma antioxidant capacity in healthy adults [4]. Edible coatings are used for extension of shelf life of fruits and vegetables. These can also be safely eaten as part of the product and do not add unfavourable properties to the foodstuff [5]. Edible coatings or films increase the shelf life of fruits and vegetables and are environment friendly [6].

The most peculiar properties of proteins compared to other film-forming materials are denaturation, electrostatic charges, and amphiphilic character. Protein conformation can be affected by many factors, such as charge density and hydrophilic–hydrophobic balance. Proteins have good film-forming properties and good adherence to hydrophilic surfaces [7].

Protein-derived films provide good barriers to O2 and CO2 but not to water [8]. Their barrier and mechanical properties are impaired by moisture owing to their inherent hydrophilic nature [9]. Soy protein is a side-product of soybean oil industry and production of biodegradable films has the potential to add value to soy protein.10 In general, SPI films provide limited resistance to water vapor transfer due to the inherent hydrophilicity of proteins [11, 12]. Several studies mentioned to storage of mangosteen fruit.

The application of technologies to extend the postharvest life of mangosteen fruit was studied and compared to storage at 25 °C/70-75%R.H (25 °C control treatment). The fruits were packed in expanded polystyrene (EPS) trays (5 fruits/tray). Five treatments were carried out at 13 °C/ 90-95% RH: application of carnauba wax coating, lecithin + CMC (carboxymethyl cellulose) coating, 50 μm LDPE (low density polyethylene) film coating, 13 μm PVC (Polyvinyl chloride), and non-coated sample (13 °C control treatment). Physicochemical analyses were performed twice a week. A statistical design was completely randomized with 8 repetitions for each treatment plus the control treatment.

The results were submitted to variance analysis, and the averages compared by the Tukey test at 5% probability. Among the quality parameters analyzed, more significant differences were observed for weight loss, texture, and peel moisture content. The results showed that the maximum storage period for mangosteen at 25 °C is two weeks; while storage at 13 °C can guarantee the conservation of this fruit for 25 days [13]. Storage temperatures between 4 and 8 °C can be used to prolong the shelf life of mangosteen, but with storage at low temperatures, the hardening of the pericarp reduces the overall consumer acceptability of the fruit due to the difficulty of cutting it open [14].

Storage of mangosteen at 12 °C produced acceptable levels of chilling symptoms, and therefore resulted in the longest storage life (20 days) [15]. Edible coatings, such as carnauba wax, have also shown to be good alternatives for improving fruit storability. Wax is used to reduce mass loss (moisture) and, consequently, softening and wilting; it also gives the fruit a more shiny appearance improving its visual quality [16]. Mangosteen (*Garcinia mangostana* L.) fruit were harvested when the peel (pericarp) was light greenish yellow with scattered pinkish spots. Fruit were exposed to 1 μL L−1 1-methylcyclopropene (1-MCP) for 6 h at 25 °C and were then stored at 25 °C (control) or 15 °C. The 1-MCP treatment only temporarily delayed softening of the fruit flesh, during storage. Storage life, defined as the time until the pericarp was dark purple, was much longer in fruit stored at 15 °C than in fruit stored at 25 °C.

It was also longer in 1-MCP treated fruit (storage life at 15 °C: control 18 d, 1-MCP-treated fruit 27 d). The 1-MCP treatment also increased the length of shelf life, defined as the time until the pericarp turned blackish purple or showed calyx wilting, at 25 °C. 1-MCP treatment reduced ethylene production. It also reduced pericarp levels of 1-aminocyclopropane-1-carboxylic acid (ACC), and the pericarp activities of ACC synthase (ACS) and ACC oxidase (ACO). In the fruit flesh, in contrast, 1-MCP did not affect ACC levels and ACS activity, but the treatment reduced ACO activity. Taken together, both the storage life and the shelf life of the fruit were extended by the 1-MCP treatment.

A decrease in ACO activity largely accounted for the effects of the 1-MCP on ethylene production in the pericarp [17]. Regarding to the application of soy protein isolate as edible film coating in preservation of fruits, there were also some remarkable studies mentioned. Preservation properties of soy protein isolate (SPI)/nano-SiOx composite coatings to apple fruits were investigated [18]. Effectiveness of edible coatings containing soy protein isolate (SPI), in reducing oxidative browning and moisture loss during storage of cut apples, potatoes, carrots, and onions was investigated. The SPI coatings were shown to have antioxidative activity.

Furthermore, addition of carboxymethyl cellulose (CMC) to the formulations significantly improved its antioxidative activity [19]. A soybean protein isolate (SPI)-chitosan edible coating was used to prolong the shelf life of apricots stored at 2 °C [20].

Mangosteen is a tropical fruit that undergoes postharvest deterioration rapidly. It's a highly perishable fruit and easily damaged, softens very rapidly during ripening, and becomes mushy and difficult to consume fresh. Application of soy protein isolate as edible coating could be considered as a useful approach to maintain its product quality during preservation. Objective of the present study focused on the effect of soy protein isolate coating on some physicochemical, microbial and sensory characteristics of mangosteen during preservation.

Materials & Method

Material

Mangosteen fruits were collected in Binh Duong province, Vietnam. They must be cultivated following VietGAP to ensure food safety. After harvesting, they must be conveyed to laboratory within 8 hours for experiments. Fruits were thoroughly rolled to remove dirt, dust and adhered unwanted material. Besides mangosteen fruits we also used other materials during the research such as soy protein isolate, distilled water, NaOH, 2,6-dichlorophenolindophenol**,** Petri film - 3M, Tween 80, glycerol, PVC bag. Lab utensils and equipments included colony counter, refrigerator, pH meter, refractometer, digital balance, grinder, centrifugator.

Figure 1: Mangosteen (*Garcinia mangostana*)

Researching Procedure

Preparation of Coat Forming Solution

The coating solution was prepared by dissolving 0, 5, 10, 15; 20 g of soy protein isolate powder in 1000 ml of distilled water for 10 h at 20°C to dissolve soy protein isolate to prepare 1 L of 0%, 0.5%, 1.0%, 1.5%, and 2.0% soy protein isolate solutions. Then, Tween 80 and glycerol were added in the soy protein isolate solution [21].

Coating Application

The surface of the fruits were disinfected with 2% peracetic acid for 1 min and gently rinsed with distilled water, then air-dried. Fruits were separated into three groups in triplicate; each group of the fruits was quoted as control (without treatment) 0% and 0.5%, 1.0%, 1.5%, and 2.0% soy protein isolate coating. Each group of mangosteen was divided into 20 batches in triplicate (60 batches) each containing 100±5g of whole mangosteen. They were dipped in the soy protein isolate coating solution of 0%, 0.5%, 1.0%, 1.5%, and 2.0% for 1 min and the samples were air dried for 15 min at room temperature (about 28°C). The coated fruits were packed in PVC wrap and kept at 4°C in a refrigerated condition for a period of 30 days to study the shelf life and physicochemical and microbial parameters.

Determination of Weight Loss

Three batches of mangosteen containing 100±5g of whole mangosteen were taken at an interval of three days for total storage period. The mangosteen fruits were weighed regularly to determine weight loss, which was calculated cumulatively by comparing the weights of the sample with the electronic weighing balance at an interval of 5 days for the total 30 days storage period and the results were expressed as percentages.

Measurement of pH, Total Soluble Solids, Titratable Acidity and Ascorbic Acid

5 g mangosteen pulp was homogenized in 25 ml of distilled water. Then the mixture was filtered using muslin cloth. An aliquot of 25 ml was used to measure pH with a pH meter. The TSS was measured directly from the filtered residue using a hand refractometer and expressed as brix. The titratable acidity was determined with 0.1 N NaOH. Mangosteen pulp (5g) from fruit was homogenized using a grinder and then

centrifuged at 5000 rpm for 4 minutes; the supernatant phase was collected and analyzed to determine ascorbic acid content by 2, 6-dichlorophenolindophenol titration.

Measurement of Microorganism Load

The total colony forming units (CFU) was enumerated during the storage period by Petrifilm - 3M.

Sensory Evaluation

The acceptability of the samples was evaluated through the standard sensory evaluation techniques. The sensory attributes such as visual appearance, color, taste, flavor and acceptability was carried out by selected panel of judges (9 members) rated on a five point hedonic scale.

Statistical Analysis

The experiments were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT). Statistical analysis was performed by the Statgraphics Centurion XVI.

Result & Discussion

Nutritional Composition in Mangosteen Fruit

Table 1 Nutritional composition in mangosteen fruit

Table 1: Major nutrient compositions in pulp of mangosteen (*Garcinia mangostana*)

Parameter	Moisture (g/100g)	Protein (g/100g)	Total soluble solid (°Brix)	Fibre (g/100g)	Flavonoid (µg QE/g)	Vitamin C (mg/100g)
Value	22.29±0.03	9.45±0.03	14.55±0.01	19.68±0.02	28.55±0.01	24.21±0.02

Mangosteen contained carbohydrate (37.67–95.02%) and crude protein (0.65–31.76%) as their major components. Moisture (0.45–3.42%), crude fat (1.23–19.55%), crude fiber (2.93–21.13%) and ash (1.76–5.44%) were also found at different levels, depending upon the portions. All portions of fruit were rich in macro and micro elements. The fruits also possessed phenolics (174.02–10.725mg GAE per g), flavonoid (19.25 to 99.98 µg QE per g) and alkaloid (1.56 to 9.49 mg/kg) contents [22].

Effect of Soy Protein Isolate Coating on Weight Loss of Mangosteen

The weight loss of mangosteen observed in control was due to the shrinkage of fruits by loss of moisture which was not observed in the coated fruits. The soy protein isolate coating prevented the evaporation of moisture from coated mangosteen fruits. There was a signifcant difference observed between the control and coated samples. Results were showed in Table 2.

Table 2: Effect of soy protein isolate coating on weight loss (%) of mangosteen stored at 4°C

Preservation time (days)	Soy protein isolate concentration				
	0%	0.5%	1.0%	1.5%	2.0%
0	0	0	0	0	0
5	3.24±0.02^{a}	3.19±0.02^{ab}	3.08±0.03^{b}	2.54±0.03^{bc}	2.29±0.03^{c}
10	6.15±0.01^{a}	6.02±0.00^{ab}	5.99±0.01^{b}	5.54±0.01^{bc}	5.33±0.00^{c}
15	7.59±0.02^{a}	7.40±0.01^{ab}	7.28±0.00^{b}	7.11±0.00^{bc}	6.90±0.01^{c}
20	9.64±0.01^{a}	9.43±0.01^{ab}	9.37±0.03^{b}	9.25±0.01^{bc}	8.99±0.02^{c}
25	10.13±0.03^{a}	9.95±0.00^{ab}	9.55±0.02^{b}	9.30±0.02^{bc}	9.11±0.00^{c}
30	11.49±0.00^{a}	11.21±0.01^{ab}	11.02±0.00^{b}	10.64±0.01^{bc}	10.45±0.01^{c}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

The effect of composite edible films containing soy protein isolate (SPI) in combination with additives like hydroxypropyl methylcellulose (HPMC) and olive oil on 'Babughosha' pear (*Pyrus communis* L.) stored at ambient temperature (28 ± 5 °C and 60 ± 10% RH) was evaluated. Edible coating comprising of SPI 5%, HPMC 0.40%, olive oil 1% and potassium sorbate 0.22% was found to be most suitable combination for pear fruit with predicted values of response variables indicated as weight loss% 3.50, pH 3.41, TSS 11.13 and TA% 0.513.[23]

Effect of Soy Protein Isolate Coating on Ph, Total Soluble Solids, Titratable Acidity and Ascorbic Acid of Mangosteen

Soy protein isolate coating could maintain the respiration at a minimal rate. Effect of soy protein isolate coating on pH, total soluble solids, titratable acidity and ascorbic acid of mangosteen was clearly illustrated in Table 3.

Table 3: Effect of soy protein isolate coating on pH, total soluble solids, titratable acidity and ascorbic acid of mangosteen stored at 4°C after 30th day of preservation

Mangosteen treated with	Parameters			
	pH	**Total soluble solids (o Brix)**	**Titratable acidity (%)**	**Ascorbic acid (mg/100g)**
1.5% soy protein isolate before preservation	5.65±0.02a	14.55±0.01a	9.32±0.00a	24.21±0.02a
1.5% soy protein isolate after 30th day of preservation	5.67±0.01a	14.49±0.01a	9.30±0.01a	24.18±0.03a

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Preservation properties of soy protein isolate (SPI)/nano-SiOx composite coatings to apple fruits were investigated. The sodium dodecyl sulfonate-modified nano-SiOx (SNS) particles were prepared by the ultrasonic method and the counter-ion activation method, which products were designated as USNS and CSNS, respectively.

The incorporation of CSNS particles was better than USNS to improve the preservation quality of the SPI film. The best conditions for the synthesis of the composite film were as follows: 10% SPI concentration, 0.3% nano-SiOx dosage and coating time of 60 s. Under these conditions, the climacteric peak of apples was delayed to the fifth week. The apples also had better physiological indices than the control group [18].

Effect of Soy Protein Isolate Coating on Total Plate Count (Tpc) of Mangosteen

Contamination of the fruits and vegetables flesh can occur from the skin increasing the fruits and vegetables spoilage leading to biochemical deterioration such as browning, off flavour and texture break down, decreasing the fruits and vegetables quality and the risk to the consumers due to the presence of pathogenic microorganism [24].

Table 4: Effect of soy protein isolate coating on sensory characteristics of mangosteen stored at 4°C after 30th day of preservation

Mangosteen treated with	Total plate count (TPC)
1.5% soy protein isolate before preservation	$1.1 \times 10^{2} \pm 0.01^{a}$
1.5% soy protein isolate after 30th day of preservation	$0.6 \times 10^{1} \pm 0.00^{b}$

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Incorporation of malic and lactic acid into soy protein coatings retarded microbial growth on fresh-cut melon. [25]

Effect of Soy Protein Isolate Coating on Sensory Characteristics of Mangosteen

An investigation revealed that increase in amount of SPI in formulation increased thickness of edible film whereas increase in plasticizer and pH decreased he film thickness.

As SPI concentration increased tensile strength of film increased rapidly however, as pH increased tensile strength decreased slowly. At lower pH value tensile strength of film gradually increased with increase in plasticizer concentration and further it decreased. The young's modulus and elongation at break values of edible film increased with increase in SPI but decreased with increase in plasticizer concentration [26].

Table 5: Effect of soy protein isolate coating on sensory characteristics of mangosteen stored at 4°C after 30th day of preservation

Mangosteen treated with	Sensory score
1.5% soy protein isolate before preservation	7.89 ± 0.01^{a}
1.5% soy protein isolate after 30th day of preservation	7.82 ± 0.00^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Effectiveness of edible coatings containing soy protein isolate (SPI), in reducing oxidative browning and moisture loss during storage of cut apples, potatoes, carrots, and onions was investigated. The SPI coatings were shown to have antioxidative activity. Furthermore, addition of carboxymethyl cellulose (CMC) to the formulations significantly improved its antioxidative activity. Oxidative discoloration, as determined by Commission Internationale De I'Eclairage (CIE) lightness (L∗L∗), redness (a∗a∗), and yellowness (b∗b∗) color scale, was significantly reduced ($p < 0.05$) by SPI coating treatments over a storage time of 120 min.

Loss of lightness was reduced by SPI coatings with and without CMC. These respectively showed 4.03 and 3.71% change of L∗L∗ value compared to 8.56% for control. Browning of the control in cut potatoes was significantly increased by 106.6% in contrast to 34.3 and 35.2% for SPI coatings with and without CMC, respectively. The b∗b∗ values also reflected effectiveness of SPI. Moisture barrier effect was significantly better for the treatments, compared to the control.

SPI coatings reduced moisture loss in apples and potatoes, respectively, by 21.3 and 29.6% over the control. Cut onions did not show any treatment effect both in terms of browning and moisture loss. SPI coatings prove to be good moisture barrier and antioxidative property [19]. A soybean protein isolates (SPI)-chitosan edible coating was used to prolong the shelf life of apricots stored at 2 °C. The coatings, especially the SPI-chitosan coating, significantly decreased the weight loss of apricots. Meanwhile, this treatment prevented the decrease in firmness and benefited the textural properties of the tissue [20].

Conclusion

This fruit has a very short shelf life and quickly becomes unacceptable for fresh consumption and further processing. Mangosteen is affected or damaged by insects, microorganisms, pre and post harvesting conditions during transport and preservation. Preservation of mangosteen is a big challenge for world.

Edible coating is an effective method to solve this problem. It provides protective edible covering to this fruit. It is beneficial for consumers and environment. Therefore, the mangosteen fruit should be preserved for a long shelf life without using chemical substances. We have successfully optimized some physicochemical, microbial and sensory characteristics of mangosteen during preservation. By this study, there will be an alternative approach to prolong mangosteen shelf-life during post-harvest.

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