The Malaysian Journal of ANALYTICAL SCIENCES ISSN 1394-2506

APPLICATION OF PALM STEARIN- CHITOSAN EDIBLE COATING ON STAR FRUITS (*Averrhoa carambola L.*)

(Aplikasi Penyalutan Stearin-Chitosan ke atas Belimbing (*Averrhoa carambola L.*))

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Abstract

An edible coating comprising of hydrophilic (chitosan) and hydrophobic (palm stearin) components which demonstrated gas barrier and moisture barrier properties respectively, was developed to prolong the postharvest life of star fruits (*Averrhoa carambola L.*). The physicochemical properties of the coated star fruits were evaluated in terms of weight loss, firmness, visual appearance, colour and glossiness, respiratory gases (oxygen and carbon dioxide) concentrations and ethylene concentration during storage at chilled temperature for 40 days. The results obtained showed that coating reduced weight loss, and maintained firmness and appearance of star fruits. Formulation 1:1 (chitosan:stearin) prevented decline in oxygen production, slowed down carbon dioxide production, and maintained firmness of star fruits. Visual appearance of star fruits showed that coating had lengthened the post harvest life of star fruits up to 40 days with no sign of mould growth.

Keywords: Edible coating; chitosan; palm stearin; emulsion; physicochemical properties

Abstrak

Penyalutan yang boleh dimakan yang terdiri daripada komponen hidrofilik (kitosan) dan hidrofobik (stearin) yang bertindak sebagai ciri- ciri penghalang gas dan kelembapan telah dihasilkan untuk memanjangkan hayat simpan belimbing (*Averrhoa carambola L.*). Ciri-ciri fisikokimia buah yang disalut telah dianalisis dari segi kehilangan berat, kekerasan buah, keadaan visual buah, warna dan kilatan, kepekatan gas respirasi (oksigen dan karbon dioksida), dan kepekatan etilena ketika buah disimpan pada suhu dingin selama 40 hari. Keputusan menunjukkan buah yang disalut mengurangkan kehilangan berat, mengekalkan kekerasan dan keadaan fizikal buah. Formulasi 1:1 (kitosan:stearin) menghalang kemerosotan penghasilan oksigen, melambatkan penghasilan karbon dioksida tetapi menaikkan penghasilan etilena. Keadaan visual belimbing menunjukkan salutan memanjangkan hayat simpan belimbing sehingga 40 hari tanpa pertumbuhan kulat.

Kata kunci: salutan yang boleh dimakan; kitosan; stearin; emulsi; ciri fizikokimia

Introduction

Recently, consumers around the world demand fresh food of high quality without chemical preservatives and with extended shelf life forcing the food industry to develop better methods. One method of extending post harvest shelf life is the use of edible coatings. Proteins, lipids, and polysaccharides are the main constituents of edible coatings. Due to their hydrophobicity, lipid compounds have been used as edible coatings to prevent moisture exchanges between the food product and the surrounding medium. Many studies focusing on lipid coating permeability have reported that the moisture barrier properties of some fatty food grade coatings are comparable with synthetic films such as low-density polyethylene or polyvinyl chloride [1]. However, the performance of lipid films against mass transfer resides also on their structural integrity. Solid lipids are generally brittle and cannot form cohesive layers. Therefore in edible films and coatings, they usually need a support structure matrix such as polysaccharides or proteins to attain better mechanical properties.

Proteins and polysaccharides generally form film with good mechanical properties. They are also better gas barriers since hydrocolloids exhibit moderately low permeability to gases. However, they are poor moisture barriers because of their hydrophilicity. Improved film performances can be obtained when hydrocolloids (proteins or polysaccharide) form a continuous network and the hydrophobic substances (lipids) provide the moisture barrier properties. However, constituent compatibility is an important issue dealing with mixtures of biopolymers, and this might drastically alter the performance of composite films [2]. Hence the exact ratios for combination of both substances (moisture and gas barriers) are very important to improve film performances.

Highly perishable fruits such as berries and tropical fruits are appropriate products to be protected with coatings because they exhibit a short storage life. Star fruits have a relatively long storage life compared to many tropical fruit but are easily damaged especially after harvest because they are very susceptible to mould growth [3]. According to a study, star fruits stored in normal atmosphere storage were totally engulfed by mould within a few weeks, and after one month they were completely spoiled [4]. In Malaysia, high cost of polystyrene packaging affects the exporting of star fruits to Europe [5].

Palm stearin is the solid fraction obtained by controlled temperature fractionation of palm oil. It is available in a wide range of melting point and iodine value. However, it has low plasticity and does not completely melt at body temperature. Currently, there is an increasing interest in the use of chitosan as edible fruit coating because of its potential to inhibit fungal growth and extend the shelf life of fruits [6-8]. However, little research had been done using chitosan which is incorporated with lipid constituents such as palm stearin which is a cheap palm oil fraction, making it a cost effective ingredient in the application of edible fruit coating. Therefore, the aim of this study was to investigate the potential of stearin-chitosan coating on the extension of the storage shelf life of star fruits and also to investigate the influence of different concentrations of stearin-chitosan coatings on the physicochemical characteristics of the star fruits during chilled storage.

Materials and Methods

Materials

The raw materials included star fruits and palm stearin. Refined Bleached Deodorised (RBD) palm stearin was obtained from Cargill Specialty Fats (M) Sdn. Bhd., Pelabuhan Kelang, Selangor, Malaysia. Star fruits at maturity index 2 of uniform size and free from external defects were obtained from Selangor Fruit Valley, Batang Berjuntai, Selangor, Malaysia. Chitosan, with deacetylation degree of 85% was purchased from Chito-Chem (M) Sdn. Bhd., Parit Buntar, Perak, Malaysia. 99% glacial acetic acid and Tween 80 were used to obtain coating solution.

Preparation of the coating emulsions

Chitosan (1% w/v) was dispersed in an aqueous solution of glacial acetic acid (1%, v/v), at 40˚C. After the chitosan was completely dissolved, the previously melted (at 60^{0}C) palm stearin was mixed with the chitosan according to the ratio chitosan:stearin 1:0, 1:1, 1:2, 1:3, 2:1, 3:1 and 0:1. Then Tween 80 (0.1% v/v) was added. These mixtures were emulsified at 13 500 rpm for 4 min [9].

Coating application

Coating application including selection of star fruits, washing, dipping and storing were conducted as in the methods reported previously [10,11]. The selected star fruits were washed using distilled water containing 200 ppm of sodium hypochlorite solution and then they were drained. The fruits were dipped in the coating solutions for 1 min except for fruits coated with C:S =3:1. The C:S= 3:1 coating was applied on fruits by using a clean and soft brush. Control samples followed the same treatment of washing and dipping technique but samples were dipped in distilled water. After air-drying, the fruits were stored in perforated boxes at chilled temperature (4-7 ˚C) and RH in the range of 90-98% until analysis was carried out..

Determination of physicochemical properties

Physicochemical properties of samples were performed at 1, 5, 10, 15, 20, 25, 30, 35 and 40 days of storage at chilled temperature (4˚-7˚C). Each analysis was carried out in three replicates.

Determination of weight loss

The weight loss was determined by weighing the samples on a laboratory digital balance (A & D HF-300, Japan). The results were then expressed as percentage loss of moisture based on the original weight[12].

Determination of gas concentration

Carbon dioxide and ethylene concentrations were measured by placing a fruit in a plastic jar, hermetically sealed with a rubber stopper for 2 h. One millilitre of the atmosphere was withdrawn in a gas syringe. Carbon dioxide and ethylene concentrations were quantified using a Gas Chromatography (Agilent 78990A) equipped with Thermal Conductivity Detector (TCD) and Flame Ionization Detector (FID), respectively. The column and detector temperatures were 60˚C and 180˚C, respectively. Results from the means of triplicate determinations for each one of the replicates were expressed as ppm [13]. For oxygen concentration determination, a portable oxygen and carbon dioxide analyser (Mocon Pac-Check Model 325, USA) was used. The results were expressed in percentage.

Determination of firmness retention

For each fruit, texture was determined using a TA-XT2i Texture Analyzer (Stable Microsystems, Surrey, UK) equipped with a compression cell of 5 kg and a cylindrical and flat acrylic probe of 1 cm in diameter, using 1 mm/s crosshead speed, a 1 N force and a 75% strain to penetrate the fruit. The results were expressed as percentage of firmness retention (compression force during storage time was compared to force on day 1) [10].

Determination of surface colour and visual appearance

Surface colour was determined using glossimeter (Multi-Gloss 268, Minolta, Langenhagen, Germany) while appearance of star fruits was determined through observation

Results and Discussion

Weight loss

Weight loss which occurs during fruit storage is normally due to its respiratory process, the transference of humidity and some process of oxidation [14]. It can be observed in Figure 1 that the weight loss of star fruits increased with storage time, for all treatments. When star fruits were coated with only chitosan (C: S= 1:0), the weight loss was reduced as compared to the uncoated star fruits. However, when stearin was incorporated with chitosan with the ratio of 1:1 (C:S=1:1), the coating significantly reduced the weight loss of star fruits as compared to the control ($P<0.05$). These results showed that the interaction of chitosan and stearin formed compact network which led to the decrease of water permeability of the coating hence, reducing the weight loss of star fruits. Similar results could also be observed for star fruits coated with only stearin (C: S=0:1) which can be explained by the hydrophobicity of stearin.

On the other hand, the increase of chitosan or stearin concentrations resulted in higher weight loss in comparison to the star fruits coated with C:S=1:1. This result was due to the flaking of the coating which increased the water vapour transference.

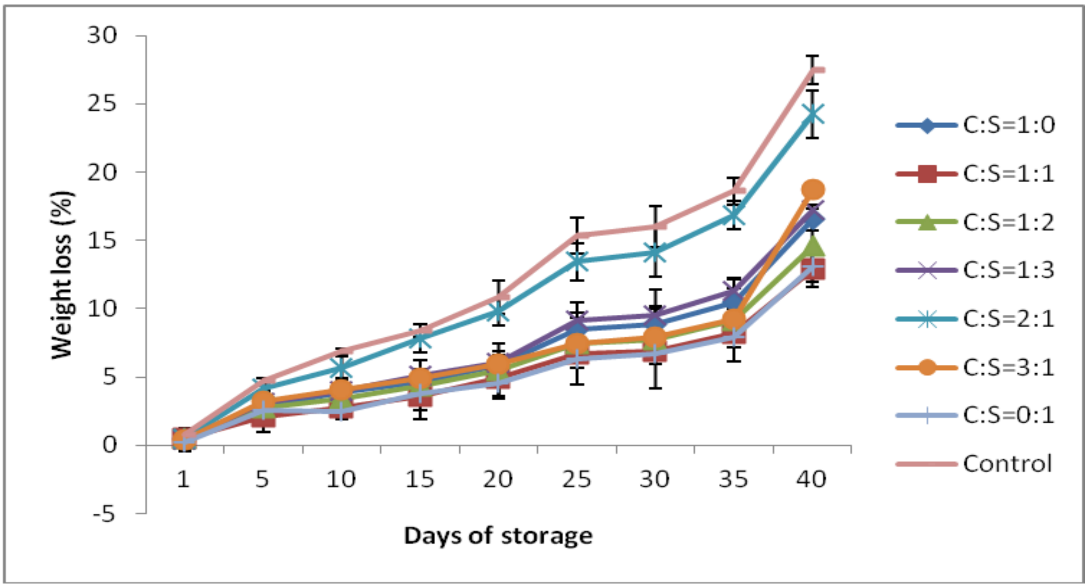


Figure 1. Effect of coatings on weight loss of star fruits stored at chilled temperature.

Gas concentrations

Ethylene concentration

Determination of ethylene concentration during storage is very important since it gives the trend of ripening of the fruits. Ethylene released from a fruit triggers the fruit to ripen. In order to prolong the shelf life of fruits, ethylene production should be slowed down. Figure 2 shows the concentration of ethylene production had been reduced by the application of coatings. However, no consistent patterns could be observed for all formulations. This might be due to the fact that the production of ethylene released by star fruits did not not follow the trend of ethylene released by climacteric fruits since star fruits are non climacteric fruits. One study reported similar results on star fruits during 30 days of storage at 2˚C and 10˚C where the fruits did not show a significant ethylene production trend [11] while another study failed to detect ethylene production during ripening of star fruits stored at 5˚C [15].

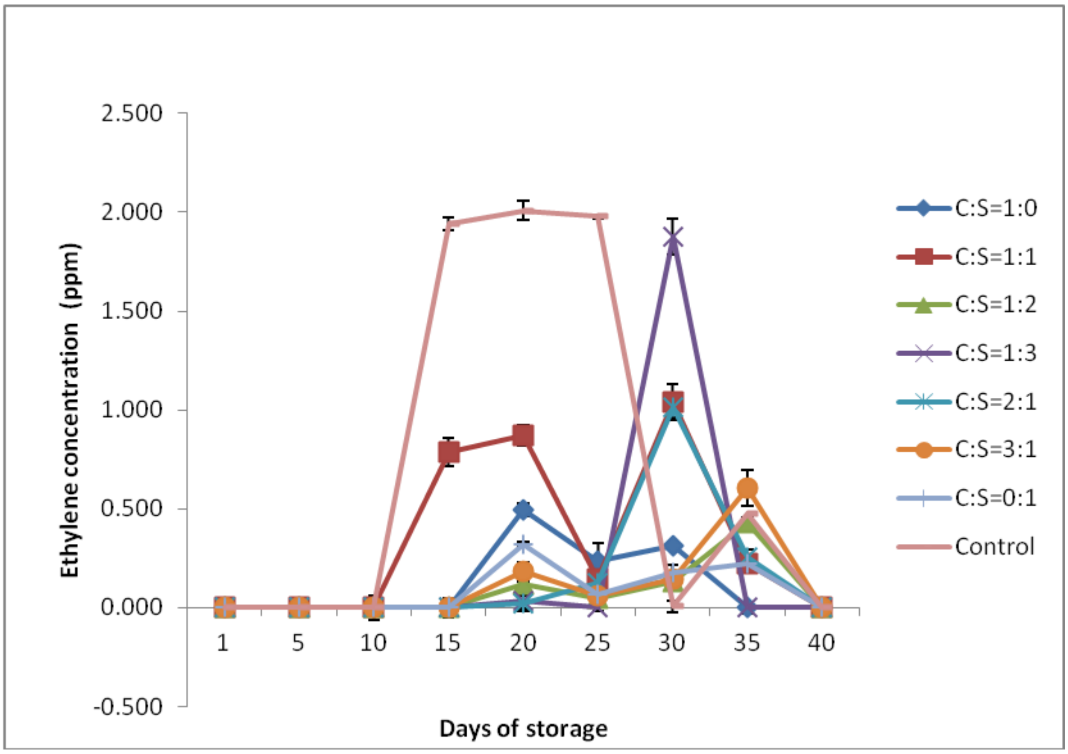


Figure 2. Ethylene concentration of star fruits stored at chilled temperature

Respiratory gases (Oxygen and Carbon dioxide) production

Besides ethylene, carbon dioxide released from fruits is also important to be measured because during respiration, carbon dioxide is released while oxygen is consumed by fruits. Coating could affect the respiratory process through the reduction of carbon dioxide and oxygen permeability. Figure 3 shows the trend of carbon dioxide released from star fruits which followed a sigmoidal pattern, in agreement with the results obtained in another study [11]. As expected, the production of carbon dioxide was higher for coated star fruits with stearin (C:S=0:1) as compared with other formulations since lipid is a poor gas barrier. However, when stearin was combined with chitosan (C:S=1:1), the coating significantly reduced the concentration of carbon dioxide ($P<0.05$) showing that the coating has low permeability to gases as a sign of a good gas barrier.

For oxygen concentration as shown in Figure 4, coated star fruits showed that the loss of oxygen from fruits has been controlled, indicating a delay in ripening. For oxygen and carbon dioxide concentrations, the formulation with stearin (C: S=0:1) had less effect on controlling the respiratory gases. This could be due to the size and distribution of lipid globules of the coating which could reduce the evenness of coating on the fruits, thus affecting gas permeability.

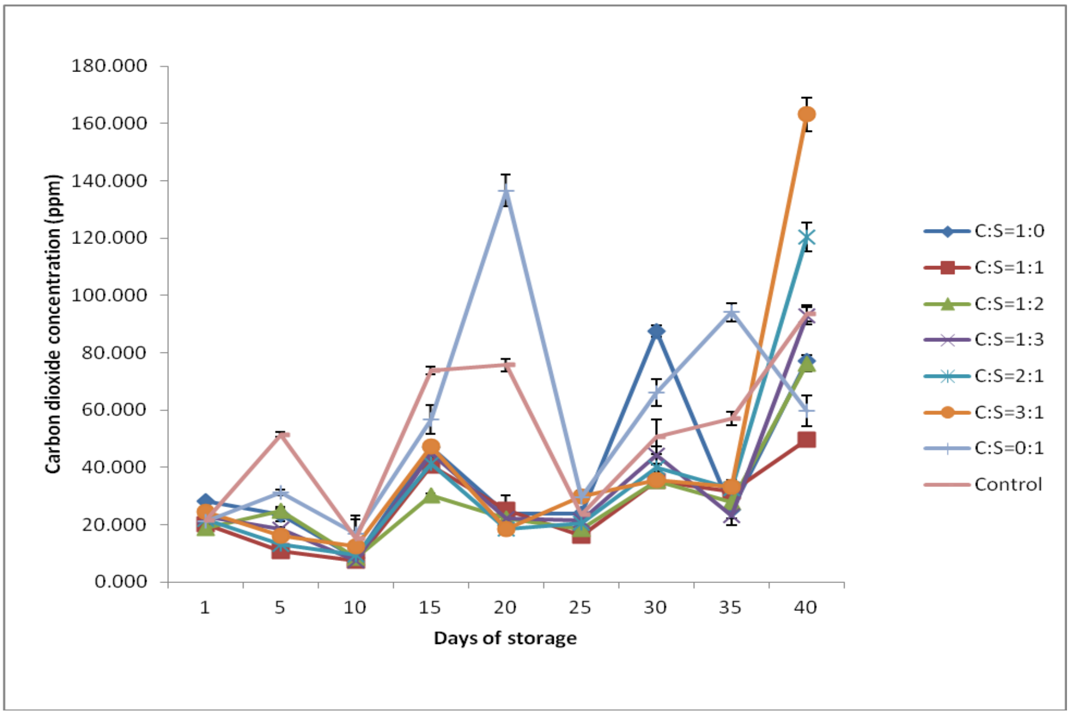


Figure 3. Carbon dioxide concentration of star fruits stored at chilled temperature

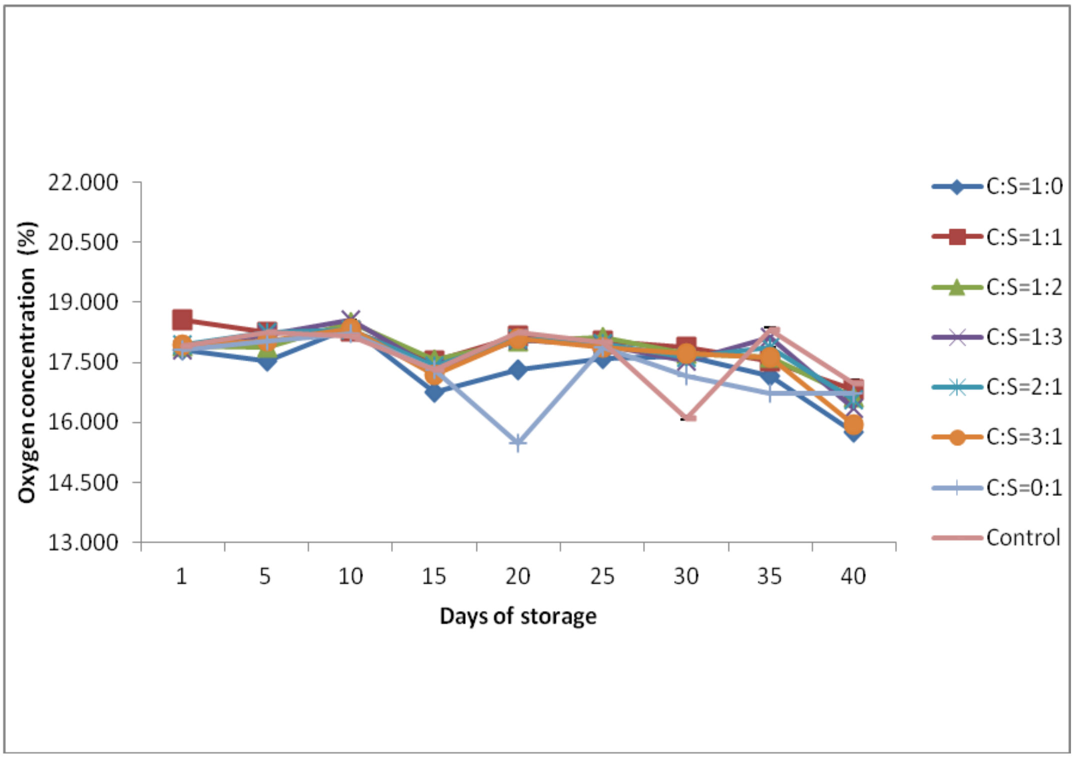


Figure 4. Oxygen concentration of star fruits stored at chilled temperature

Firmness retention

During storage, firmness of star fruits decreased due to the cell wall breakdown, as well as sample water loss. Coating acts as a gas barrier which slows down the outward loss of carbon dioxide and inward movement of oxygen, while still allowing for respiration. Low oxygen and high carbon dioxide concentrations reduce the activity of enzymes and allows retention of firmness of fruits during storage [16].

Figure 5 presents the results of firmness retention of star fruits. It was observed that coated star fruits with the same ratio of chitosan-stearin (C:S=1:1) could maintain the firmness up to 50 percent for 40 days of storage. This is because this coating reduced weight loss and also reduced gases (oxygen, carbon dioxide, and ethylene) concentrations hence maintaining the firmness of star fruits. The effectiveness of homogeneous chitosan-stearin coating was probably due to the interaction of chitosan with stearin. This was made possible by hydrogen bonding between the electropositive hydrogen of COOH of chitosan and the electronegative oxygen of the ester linkage of the triglycerides of palm stearin [17].This interaction formed a compact homogeneous network on the surface of star fruits, hence improving the quality of star fruits.

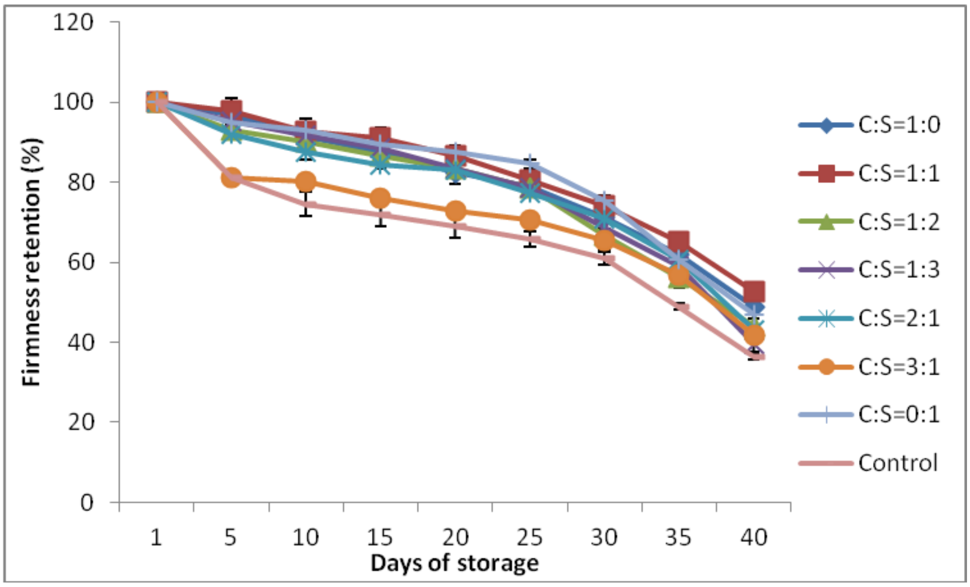


Figure 5. Firmness retention of star fruits stored at chilled temperature

Surface colour and appearance

Coating slowed down the respiration rate, reduced the colour changes of skin and flesh and increased the shelf life of fruits [12]. Based on Figures 6 the changes in colour could be observed by the increases in lightness (L*), green index (a*) and yellow index (b*) which caused the skin colour to change from green to yellow. Coating with C:S= 1:1 and C:S=1:2 underwent slower changes of colour after 25 days of storage as indicated by slower increases of a and b values as compared to the control ($P<0.05$). These results agree with the results of visual appearance (Figure 8) which showed the slower colour changes of coated star fruits with C: S= 1:1 and C:S=1:2 as compared to other formulations.

Besides colour, glossiness is another important characteristic to be measured. The smoothness of the surface is directly related to the glossiness of the fruit [18]. Based on Figure 7, C:S=1:1 showed the highest glossiness as compared to other treatments after 30 days of storage,. These results were probably due to surface desiccation and weight loss undergone by other treatments. In general, the glossiness and appearance of coated star fruits of all treatments were not significantly different as compared to the control since star fruits naturally appear glossy with an attractive colour. However, coating had prevented star fruits from mould spoilage during storage as shown in Figure 8. Visual appearance of star fruits showed that coating had lengthened the post harvest life of star fruits up to 40 days while uncoated star fruits started to show a sign of decay after 30 days of storage.

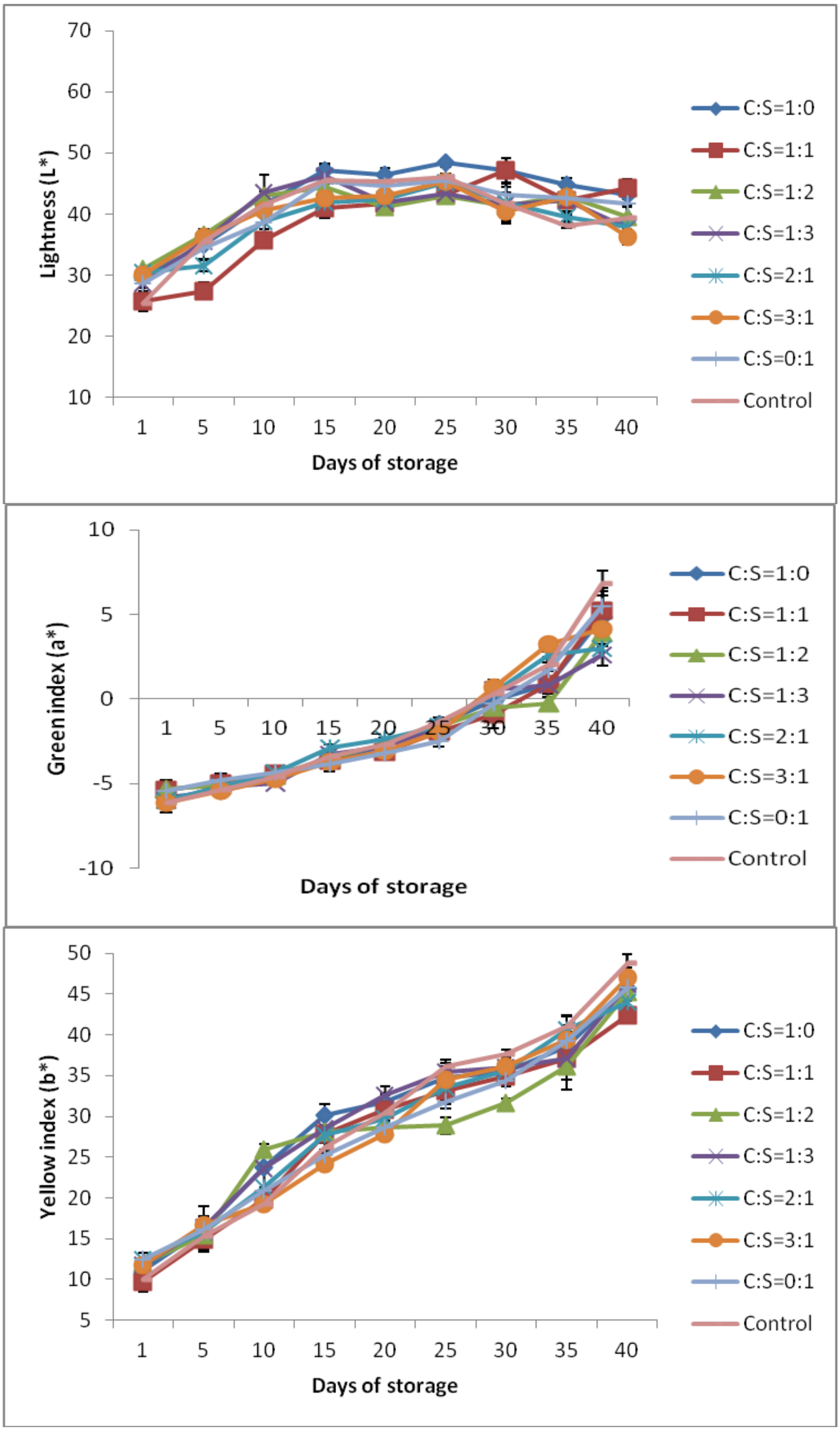


Figure 6. Lightness (L*), Green index (a*) and Yellow index (b*) of star fruits stored at chilled temperature

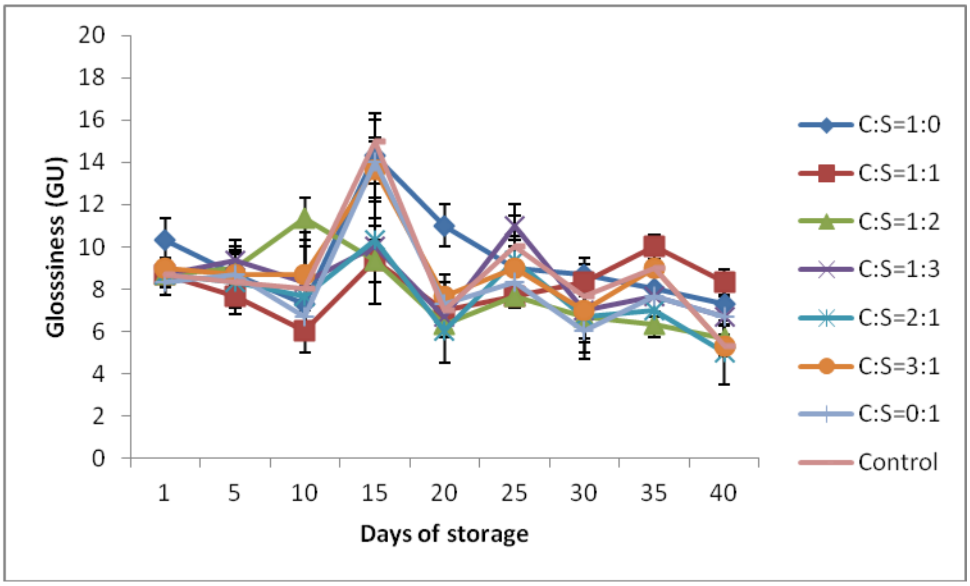


Figure 7. Glossiness of star fruits stored at chilled temperature

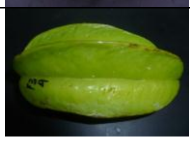
C:S	Day 1	Day 10	Day 20	Day 30	Day 40
1:0					
1:1					
1:2					
1:3					
2:1					
3:1					

Figure 8. Visual appearance of star fruits stored at chilled temperature

Conclusion

Application of chitosan-stearin edible coatings was able to improve the quality and shelf-life of star fruits during storage at chilled temperature by reducing weight loss, maintaining firmness and appearance, and slowing down respiratory CO_2 and ethylene production while preventing the decline of oxygen concentration. Overall C:S=1:1 was the best coating formulation as it showed good moisture barrier and gas barrier properties.

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