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Fibroin/chitosan based composite preservatives for longan postharvest preservation

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Abstract

During the last decades fresh fruit quality has been forced by legislative requirements to make this still important food healthier and safely. The clean food regulation in the E.U. and the U.S.A., concerning the contents of toxic pesticides and preservatives in fruits, meat, and seafood will become increasingly strict. Postharvest preservation of fresh food by safety coatings based on natural products has been received much attention of scientist all over the world. Fibroin/chitosan based composite preservatives (FCCPs) for longan postharvest preservation were prepared from silk fibroin extracted from silkworm cocoons. The tensile stress at break and water uptake, which govern the efficiency of FCCPs, were adjusted by controlling the amount of Polyvinyl alcohol (PVA) and beeswax (BW) additives. The structure and surface properties of prepared Fibroin/chitosan based membranes were characterized by Fourier-transform infrared spectroscopy (FT-IR) and Scanning electron microscope (SEM). In order to preserve longans, thin films of FCCPs were coated on the fruit peels. The results showed that fibroin/chitosan films extended shelf life, reduced browning index and percentage of spoilage rate, retarded weight loss and respiratory rate, inhibited the decrease of vitamin C, total acid content, and total sugar content of fresh longan fruit. The presence of PVA and beeswax additives found to increase the preservation potential of FCCPs. The results also showed that FCCPs can extend the shelf-life of longan fruits up to 30 days stored at 5°C and relative humidity of 90-95%, indicating their potential as an attractive alternative to improve quality of fresh fruits during storage.

Keywords: Longan postharvest preservation, silk fibroin, chitosan, composite preservatives.

1 Introduction

Many longan postharvest preservation techniques, including refrigeration, chemical preservatives, edible coatings, packaging, and modified atmosphere packings have been studied (Jiang et al., 2018). Sterilization with SO₂ and dipping in fungicides to prevent longan fruit from rot and browning leave sulphite residues and toxic components that can have adverse effects on human health (Thavong et al., 2010). Edible coating from polysaccharides, proteins, resins and lipids provides a promising method for improving the quality and extending the shelf life of fruits and vegetables (Jiang et al., 2018; Wang et al., 2013). Chitosan coating on fruit and vegetable could help lessen moisture loss and slow respiration by reducing fruit oxygen uptake from the environment (Romanazzietal., 2018) and has been successfully applied in enhancing the storability and quality of many postharvested fruits (Jiang et al., 2018; Thavong et al., 2010; Romanazzietal., 2018). Although chitosan films can prolong storage time of many fruits, but modifications of chitosan including combination of chitosan-limonene and of chitosan-nanosilica (Shi et al., 2013; Maleki et al., 2018) can increase the physical properties such as strength, water permeability and gas permeability of chitosan films and improve storability further. Silk fibroin has been investigated for textile, biomedical, photonic, and electronic applications (Rockwood et al., 2022). Recently, fruits such as strawberries and bananas have been preserved effectively by fibroin coating (Marelli et al., 2016). The formation of micrometer-thin silk fibroin films around the fruits helps managing postharvest physiology of the fruits. Silk fibroin films have suitable water uptake but brittle which reduce the mechanical

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stability of coatings. Recently, laminate and blend membranes were prepared laminate and blend membranes from silk fibroin and chitosan (Rockwood et al., 2022). Due to the linkage between the functional groups of chitosan and fibroin, the laminate membranes have high mechanical strength and elasticity while blend membranes with suitable ratio have rather high mechanical strength. These results showed a new trend of biodegradable polymer production with special properties.

In this work, fruit preservatives were prepared from fibroin, chitosan and some additives. Firstly, fibroin and chitosan based membranes were prepared and their tensile stress at break and water uptake were determined to find the suitable ingredients for forming fruit preservative coatings. Next, to increase the mechanical strength and control the water uptake, PVA and BW (hydrophobic lipid) were introduced to fibroin/chitosan mixture to form FCCPs. To preserve longans, obtained FCCPs were coated on longans' shell using dipping technique. Nutritional and physiological characteristics of the fruits were measured to evaluate the protective effectiveness of the coated films. The results also showed that all four components (chitosan, fibroin, PAV, and beeswax) have contributed for extending the storage-life of longans during postharvest storage up to 30 days.

2 Experimental

2.1 Materials

Chitosan (MW of 100,000 Daltons and deacetylation degree of 90%) was supplied by Chitosan Vietnam Manufacturing and Trading Co., Ltd. Waste silkworm cocoons was purchased from My Duc district, Hanoi, Vietnam. NaOH (99.5%), glycerol (99.5%), ethanol (99.5%), acetic acid (98%), Na₂CO₃ (99%), CaCl₂ (99.6%), gelatine and poly vinyl chloride (PVA) were supplied by Guangdong Guanghua Chemical Factory, China. BW was purchased from Vietnam Bee Development Joint Stock Company.

2.2 Silkworm cocoons degumming and fibroin fiber dissolution

Degumming silkworm cocoons

Waste silkworm cocoons were cleaned from any impurities and cut into small pieces. Silkworm cocoons pieces were then boiled in 0.02M Na₂CO₃ solution for 30 minutes, followed by rinsing with deionized water 3 times, and drying overnight at 70°C (Fernandez et al., 2012).

Fibroin fiber dissolution

Degummed silkworm cocoons were dissolved in a mixture containing CaCl₂, ethanol, and water at 80°C for 25-30 minutes until the silk was completely dissolved (Fernandez et al., 2012). Resulting homogeneous mixture was filtered to remove the insoluble fraction. Excess glycerol and ethanol were added to precipitate fibroin. The resulting mixture was centrifuged to separate fibroin.

2.3 Preparation of fibroin/chitosan based composite membranes

Mixture of fibroin in water (5%) contained in a 15 cm x 12 cm glass tray was dried at 37°C for 12 hours to create a fibroin film. Chitosan was dissolved in 1% acetic acid solution (solid/liquid ratio is 2% w/v) to form a homogeneous solution. Then obtained mixture was dried overnight at 37°C to evaporate the solvent. To create fibroin-chitosan membranes, different amounts of fibroin were dispersed to the 2% chitosan solution and then membrane formation process was performed as described above.

Similarly, Fib - Chi - PVA membrane was prepared by addition of PVA to the mixture of fibroin and chitosan before forming membrane. Fib-Chi-PVA-BW membrane was prepared by addition of PVA and BW to the mixture of fibroin and chitosan before forming membrane.

Membrane FT-IR and SEM measurements

FT-IR of membranes was measured using 6700–Thermo Nicolet–Thermo, SEM of membranes was measured by Joel 6490 JED 2300. Load at break of membrane was measured using Universal Testing Machine, AG-5kNXPlus (for load at break) and Micrometer Mitutoyo MDC-125MJB (for thickness) according to ISO 527 (2012) standard. Tensile stress at break (MPa) was calculated by the following formula (1):

$$\sigma_b = \frac{F_B}{A} \quad (1)$$

σ_b = Tensile stress at break (MPa)

F_B = Load at break (N)

A = Initial cross section of the specimen (mm²)

Water uptake

Squared (2 cm x 2 cm) membranes were kept under stable conditions of temperature and humidity (23°C ± 2°C, 50 ± 5 %) for 24 h (Fernandez et al., 2012; Garido-Herera et al., 2006). Then membranes were weighed (m_1) and soaked in water for one hour. The water excess was blotted from the surface of the squares using filter paper, and after that, membranes were weighed (m_2). Three replicates were carried out. Water uptake of the membrane (W_c , %) was calculated by the following formula (2):

$$W_c = \frac{(m_1 - m_2)}{m_1} \quad (2)$$

2.4 Preparation of preservatives

To evaluate the protective effect of preservatives made of different ingredients, 6 preservatives were prepared by

the following ways:

15 g of fibroin was added to a beaker containing 1000 mL of 2% acetic acid solution, the mixture was continuously stirred until dispersing completely fibroin. 15 grams of chitosan was slowly added to the mixture while continuously stirring at 350 rpm. Then the mixture was stirred for 2 h to get homogeneous gel labelled by Chi-Fib sample.

1 g of PVA was slowly introduced to 1000 mL of Chi-Fib sample while stirring continuously, the resulting mixture was stirred until the PVA is completely dissolved to get Chi-Fib-PVA sample.

0.15 g of surfactant was dispersed in 15 mL of water and then 0.6 g of molten BW was added to form a homogeneous mixture. The resulting mixture was then dispersed into the 1000 mL of Chi-Fib sample and stirred for 30 min to obtain the Chi-Fib-BW sample.

Complete all the above steps to obtain the composite sample FCCP.

2.5 Coating and storage of longan fruit

Longan fruits were harvested at the correct technical maturity; leaves, crushed and rotten fruits were removed, and long stems were cut. Selected fruit samples were distributed randomly into groups of 300 fruits. Seven different treatments were used: (1) control (acetic acid coating); (2) fibroin coating; (3) chitosan coating; (4) Chi-Fib coating; (5) Chi-Fib-PVA coating, (6) Chi-Fib-BW coating, (7) composite sample (Fib-Chi-BW-PVA) coating. All the treatments were performed in triplicate. The fruits were dipped into the 6 corresponding preservatives for 4 min. An aqueous solution of acetic acid (2%, v/v) was used for the coating control samples. Each group was placed in a polyethylene bag. All the samples were stored at room temperature with 90–95% relative humidity.

The changes in the quality of the longan samples during the storage period were monitored every 5-10 days (until the spoilage rate is greater than 10%) to evaluate the preservation effectiveness of the preservatives (Wang et al., 2013).

2.6 Evaluation of quality of longan fruits during storage

Respiration rate

Ten longan fruits were sampled for measuring the fruit respiration rate (Garido-Herera et al., 2006), the respiratory rate was determined using an ICA250 (UK) analyzer. In detail, ten coated longan fruits were placed in glass jar and incubated at room temperature (28°C) for 1 h. The glass jar had air-tight screw caps and rubber septum to allow headspace sampling. Percentages of carbon dioxide were recorded when the readings were stabilized. The results were calculated and expressed as $\text{ml CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$.

Weight loss

For each treatment, the measurement of weight loss of ten fruits in each replication was carried out. The weight loss was determined gravimetrically using analytical balance (Kern ALJ 250-4A). The percentage of weight loss of longan fruits during storage was calculated via comparison to the weight of the fruits on storage day 0 (Lin et al., 2017).

Total soluble solids, titratable acid and ascorbic acid

Tissue (20 g) from 5 fruit pulp was homogenized in a grinder and then centrifuged for 20 min at 15 000 g Beckman J20-2). The supernatant phase was collected for analyses for: total soluble solids, using a hand refractometer (PAL-1, Japan, 0-53°Brix); titratable acid and ascorbic acid were determined with 0.1 M NaOH, and 2,6-dichlorophenolindophenol (Chen et al., 1987). Total acid and total soluble solids were presented in %, while the vitamin C content was presented in mg%.

Percentage of spoilage

The percentage of spoilage is expressed as the ratio of the damaged fruit mass to the total fruit mass of the sample. Fruit is considered to be rotten when the surface of the rind appears mould or the rind turns dark brown.

Color change

The color change of the pods was determined using a Color Tec PCM Meters that measure 3 values L, a, b. The spectrophotometer was calibrated with black calibration light trap and calibrated instrument white tile. For each treatment, peel color of ten individual fruits per replicates was measured. Readings were taken from stem end, mid region, and blossom end of each fruit (Chen et al., 1987). The color change (ΔE_{ab}) was then determined using the following equation:

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

3 Results and discussion

3.1 Propertieess of membranes

Tensile stress at break and water uptake

The results show that the fibroin membranes are less stable than chitosan membranes (Tab. 1), however, they have lower water uptake which can decreases the moisture loss of fruits and increase their durability. Chitosan membranes have higher tensile stress at break and high water uptake. Therefore, it is recommended to use both

fibroin and chitosan for preparing membranes having better mechanical properties.

Blend membranes have higher water uptake than single membranes because of the formation of cross-linking between the chitosan and fibroin macromolecules. When the chitosan content in the membranes is increased, the tensile stress at break increases from 26.11 Mpa at chitosan/fibroin ratio of 0.5:1 to 38.96 Mpa at the ratio of 2:1 and then gradually decreases to 24.31 Mpa at ratio of 4:1 while water uptake increases continuously from 88% at ratio of 0.5:1 to 685% at ratio of 4:1.

Table 1: Tensile stress at break and water uptake membranes

| No | Membranes | Fib:chi ratio (w:w) | Tensile stress at break (Mpa) | Water up take W_e (%) |
|----|-----------------|---------------------|-------------------------------|-------------------------|
| 1 | Fibroin | 1:0 | 24.22 | 82 |
| 2 | Chitosan | 0:1 | 39.74 | 230 |
| 3 | Fib-Chi | 1:0.5 | 26.11 | 88 |
| 4 | Fib-Chi | 1:1 | 33.60 | 138 |
| 5 | Fib-Chi | 1:2 | 38.96 | 460 |
| 6 | Fib-Chi | 1:3 | 35.28 | 535 |
| 7 | Fib-Chi | 1:4 | 24.79 | 585 |
| 8 | Fib-Chi- PVA | 1:1 | 45.29 | 257.2 |
| 9 | Fib-Chi- PVA-BW | 1:1 | 44.50 | 143.4 |

The increase of water uptake with increasing content of chitosan in the membrane can be due to the interactions of -OH groups in chitosan and -NH₂ groups in fibroin. These interactions create a three-dimensional polymer network with large space to contain water molecules. The membrane with fib:chi ratio of 1:2 has a high tensile stress at break (sample 5) but it can be swollen when contacting to water or high humidity because of its high water uptake. From the tensile stress at break and water uptake, chitosan-fibroin mixture with 1:1 ratio was selected to prepare preservatives. When 3wt% PVA is used as an additive for Fib-Chi membrane, the tensile stress at break of the membrane increased from 33.60 Mpa to 55,290 Mpa but membrane's water permeability also increased from 138% to 357 % (sample 8,9). To reduce water permeability without changing the strength of the membrane, 2 wt % BW is added to the membrane.

FT-IR

As seen in fibroin spectrum (Fig.1), the peak of wave numbers of 3285 cm⁻¹ showed O-H and N-H stretching vibrations (Fathi et al., 2020). The bands at wave numbers of 2979 cm⁻¹ - 2923 cm⁻¹ indicated the presence of the aliphatic asymmetric and symmetric (C-H) (sp³) stretching vibrations (Bui et al., 2106; Bui et al., 20180; Bui et al., 2020). The bands around wave numbers of 1652 cm⁻¹ and 1540 cm⁻¹ were assigned to the absorption peaks of the peptide backbone of amide I (C=O stretching) and amide II (N-H bending), the bands around 1236 cm⁻¹ and 1448 cm⁻¹ to amide III (C-N stretching), and the bands at 670 cm⁻¹ to amide IV (Zhang et al., 2012). The typical vibration of C-O group in fibroin was shown by a band of wave numbers of 1059 cm⁻¹ (Fathi et al., 2020).

Due to the presence of amine groups in chitosan, bands around 1540 cm⁻¹ were assigned to amide II (N-H bending), the bands around 1407 and 666 cm⁻¹ to amide III (C-N stretching) and 670 cm⁻¹ to amide IV, respectively. The weak band at 1650 cm⁻¹ showed the small number of C = O bonds due to the incomplete deacetylation of chitin (Fathi et al., 2020).

Similarly, Fib-Chi and Fib-Chi-PVA blend membrane have all characteristic peaks of single ones (fibroin, chitosan, PVA). In Fib-Chi-PVA spectrum, the band around 1140 cm⁻¹ showed the C-O stretching vibrations in alcohol (Osuma et al., 2013) and the high intensity band at 3262 cm⁻¹ was due to high water uptake of PVA component in the membrane (Fathi et al., 2020). Because of the presence of BW the intensity of broad band around 3280 cm⁻¹ in Fib-Chi-PVA-BW becomes weaker.

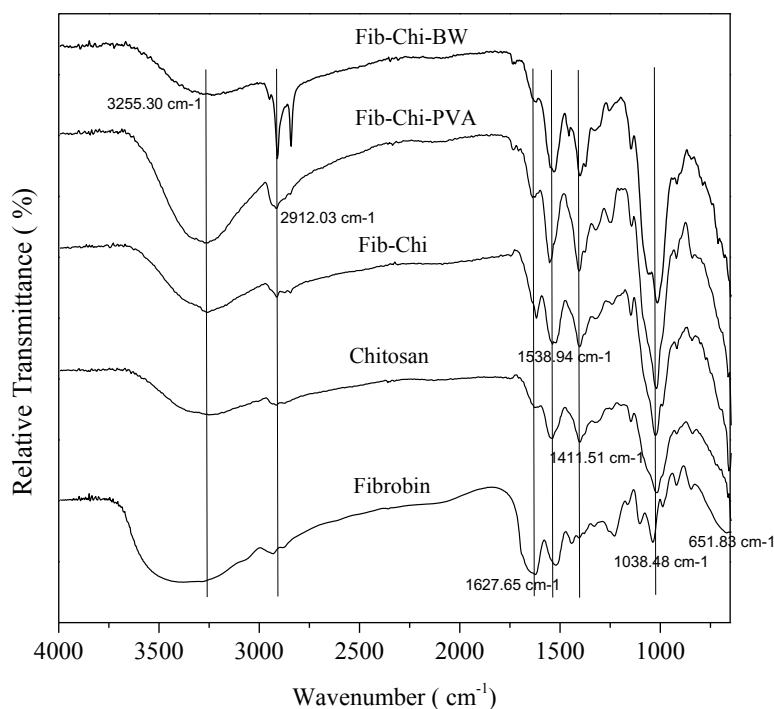
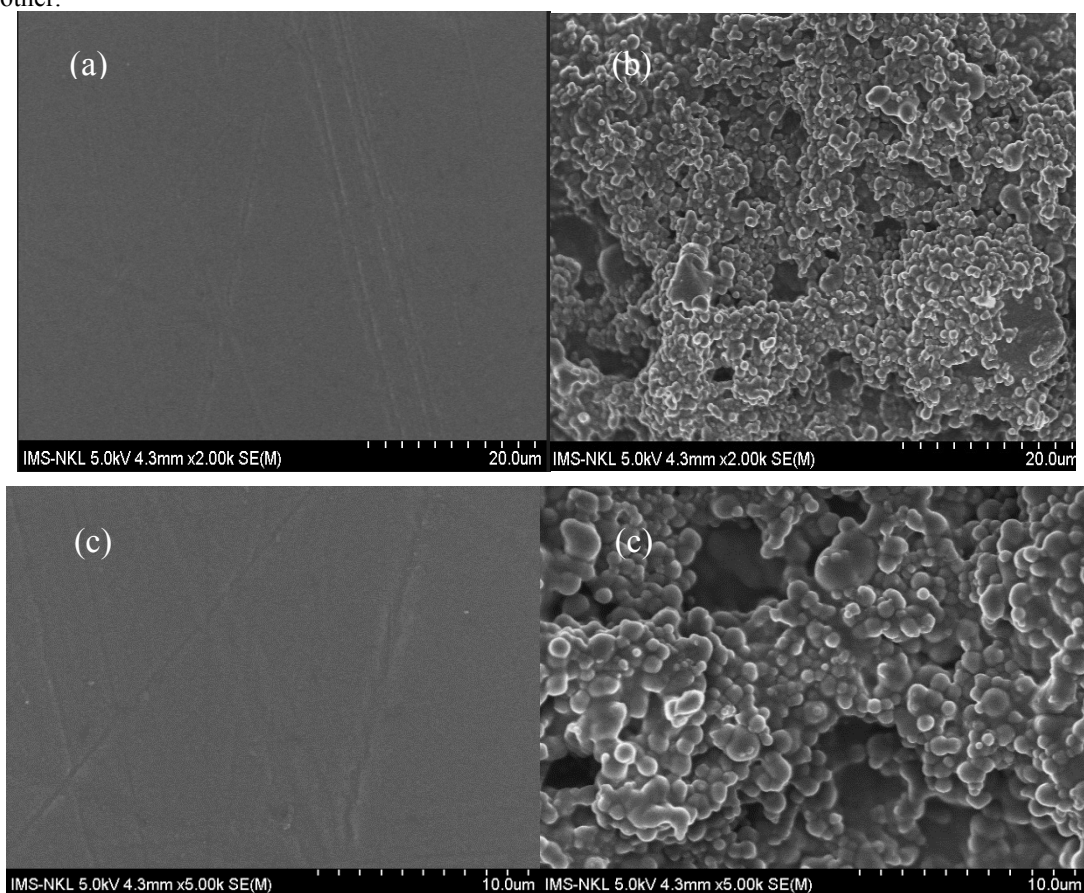


Fig. 1. FT-IR Spectra of prepared fibroin, chitosan, Fib-Chi, Fib-Chi-PVA, and Fib-Chi-PVA-BW membranes.

Morphology

SEM photographs of chitosan and Fib-Chi membranes are given in Fig. 2. The surface of chitosan membranes was homogeneous while that of Fib-Chi membranes show that chitosan and fibroin molecules are dispersed to each other.



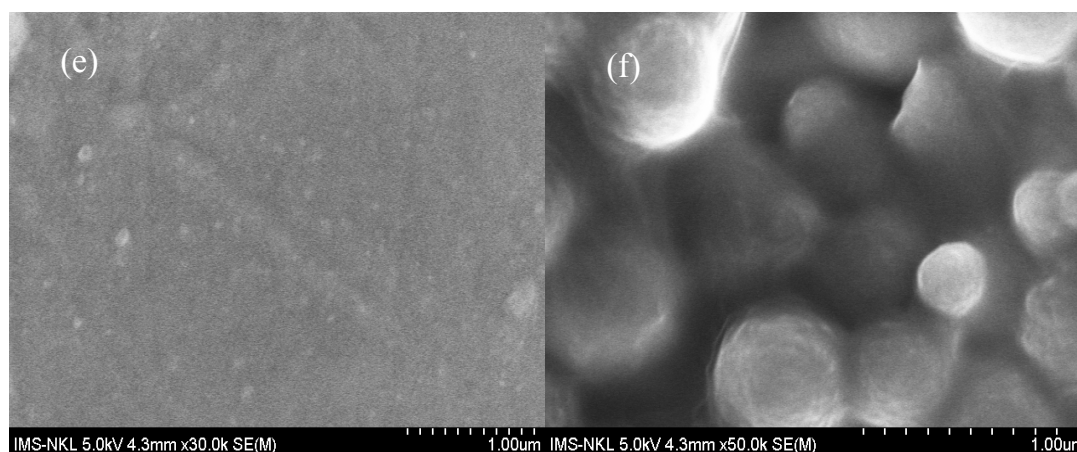


Fig. 2. SEM photographs of membranes (a,c,e) chitosan; (b,d,f) Fib-Chi.

3.2 Preservation of the coatings during storage longan

3.2.1 Influence of coating composition on the respiration rate

A rapid increase in respiration rate of the control group (Fig. 3a) was observed within the initial ten storage days (from 24.25 to 29.35 $\text{mlCO}_2 \text{ kg}^{-1} \text{ h}^{-1}$), followed by a sharp raising in the next ten days of storage (to 52.11 $\text{mlCO}_2 \text{ kg}^{-1} \text{ h}^{-1}$). The treatments of longan with fibroin and chitosan-based coatings reduce respiration rate and increased the storage time. The respiratory rate of treated longans decreases gradually in the first 10-15 storage days, then gradually increase within the next 15 and 20 days of storage and increase rapidly at 30 and 40 days. Similar results were observed by Jiang and Lin et al. when longans were coated with chitosan and treated chitosan (Lin et al., 2020; Jiang et al., 2002). The samples coated with Fib-Chi films have lower respiration rates than samples coated with chitosan or fibroin films. The addition of PVA and BW additives increase further the storage ability of films and the composite sample has the best storage ability. These can be due to the increase in tightness and the hydrophobicity of the films containing PVA and BW. After 40 days of storage, the respiratory rate of longan fruits treated with chitosan reaches 44.72 $\text{mlCO}_2 \text{ kg}^{-1} \text{ h}^{-1}$ while samples treated with composite membrane increase to 34.21 $\text{mlCO}_2 \text{ kg}^{-1} \text{ h}^{-1}$.

3.2.2 Influence of coating composition on the weight loss

The natural weight losses in all samples increase gradually with the storage time (Fig. 3b). However, during the same periods, the control sample has the highest natural weight loss (6.6% within the initial ten storage days and 11.81% in the next ten days of storage while the samples coated with preserved films have a significant reduction in the weight loss. For example, the weight loss within the initial ten storage days of longan treated with fibroin, chitosan, Fib-Chi, Fib-Chi-PVA and Fib-Chi-BW coatings reaches 3.97%; 3.77%; 3.11%, 2.62% and 2.43% while with FCCP is 1.79%. These results agree with previous research those weight loss of harvested longan (Shi et al., 2013; Lin et al., 2020) treated with chitosan were slower than untreated fruits. This is explained by the fact that coating can restrict water transfer or dehydration, gas exchange, and nutrient loss by acting as a protective barrier, and thus reduces weight loss of postharvest fruit (Lin et al., 2020). Better mechanical properties Fib-Chi film leads to a higher preservation ability of Fib-Chi film compared to Fib and Chi films. When 2 wt% of BW and 3 wt% of PVA are added to Fib-Chi film, the rate of moisture loss decreases due to BW is hydrophobic and PVA increases the tightness of the film. When both BW and PVA (composite sample) are used, the moisture loss is further reduced. The slower rate of moisture loss from the composite coated fruits may be attributed to the additional barrier against diffusion through stomata (Shi et al., 2013).

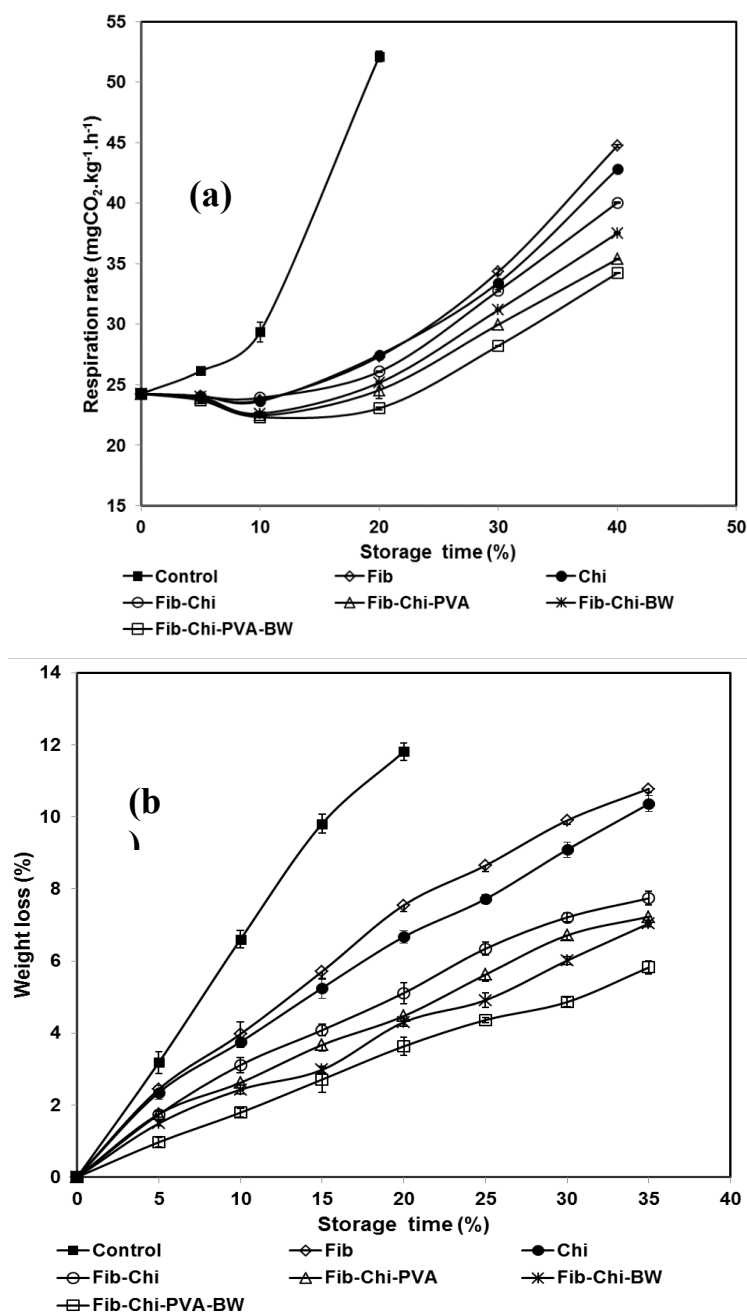


Fig. 3. Weight loss (a) and respiration rate (mgCO₂.kg⁻¹.h⁻¹) (b) of longan during storage

3.2.3 Influence of coating composition on the percentage of spoilage

The cold storage method limits the damage of longan for a short time (Fig. 4a) but after 10 days, the spoilage of the control sample was 5% and of samples coated with fibroin, chitosan, and Fib-Chi were 2.16%; 1.01% and 1.05%, respectively, while no rot was observed in Fib-Chi-PVA, Fib-Chi-BW and composite coated samples. After 15 days of storage, high spoilage rate (> 12%) was observed at the control sample while spoilage rates of samples coated with fibroin, chitosan, Fib-Chi were about 4-5%, of samples coated with Fib-Chi-PVA, Fib-Chi-BW was about 1-2%, and samples coated with composite has not been rotten. As Fig. 4a shown, after 30 days of storage, spoilage rate of samples coated with fibroin film was 15.12% and with chitosan, Fib-Chi was from 11%-14% (>10%), while samples coated with Fib-Chi-PVA, Fib-Chi-BW, and composite samples showed spoilage rate lower than 10%. The preservation effect of fibroin and chitosan-based films is probably due to the decrease in respiration and metabolic activity, which retard the spoilage process. The films form excellent semipermeable coatings around the fruits, modified the internal atmosphere by reducing O₂ and/or elevating CO₂, and suppressing ethylene evolution (Lin et al., 2020). The presence of PVA and BW additives improves the preservative properties of films; these can be due to the increase in tensile stress at break and hydrophobic property of the films.

3.2.4 Influence of coating composition on the color change

The highest significant change in color was observed at control sample (Fig. 4b), after 20 days of storage the color change (ΔE_{ab}) value of control samples reached 21.86, the pericarps were browned. However, pericarp browning was obviously inhibited in treated samples, ΔE_{ab} value of treated samples were much lower (6.85 - 10.81). The

retardation of color change in treated longan fruits could be due to the modification of internal atmosphere of the films that leads to low respiration and ethylene production rate. The treated samples have created a microclimate preservation environment with suitable temperature and humidity, which can partially limit water loss and physiological and biochemical activities, thereby inhibit activity of enzyme polyphenoloxidase existing in the cytoplasm of the pericarps.

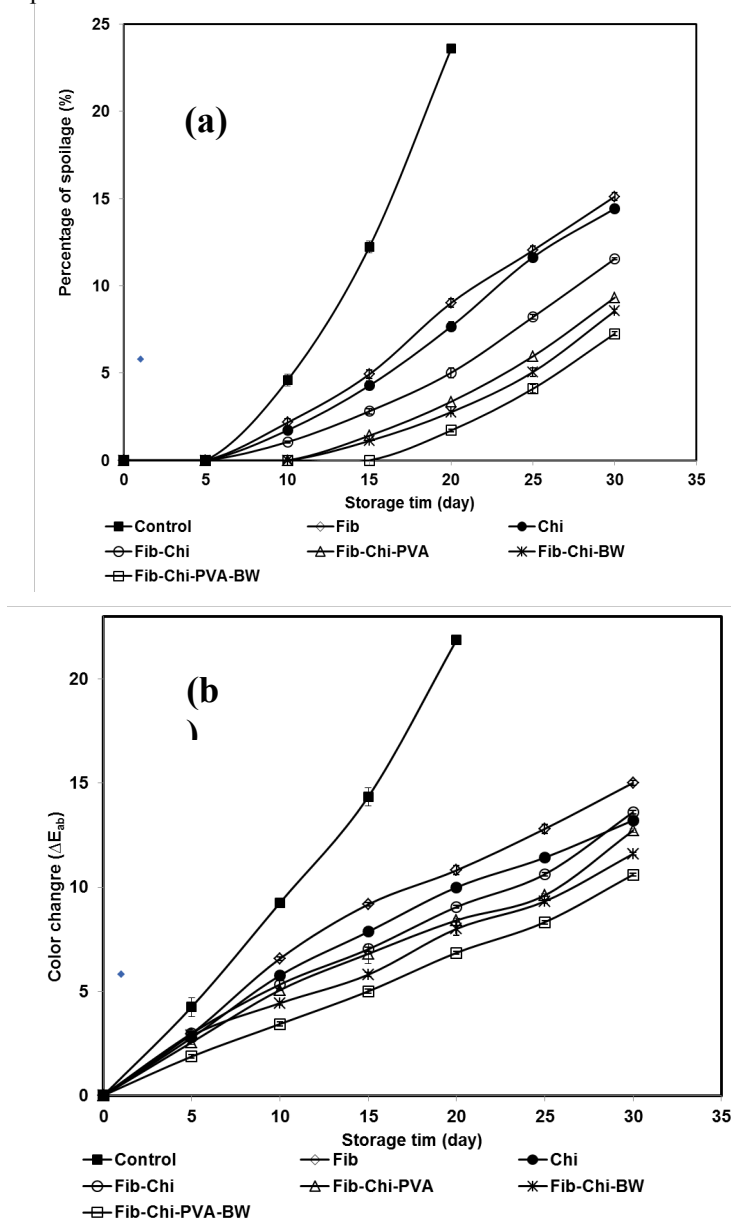


Fig. 4. Percentage of spoilage (a) and color change (ΔE_{ab}) on the pods (b) of longan during storage.

3.2.5 Influence of coating composition on the total soluble solids

TSS content of control samples decreased quickly from 19.49°Bx to 16.12°Bx during 20 days of storage (Fig. 5a) while the TSS content of treated groups decreased more slowly from 19.49°Bx to 17.41°Bx - 18.96°Bx after 20 days of storage and from 19.49°Bx to 16.55°Bx - 17.92°Bx after 30 days. The effect of coatings on reducing the TSS contents of longan fruits were probably due to the slowdown of respiration and metabolic activities, which retard the senescence process (Shi et al., 2013). Similar results were recorded in longan treated with chitosan and chitosan/nano-silica composite. In comparison to the chitosan and fibroin treated samples, Fib-Chi treated samples displayed a higher level of TSS during postharvest storage. When PVA or BW, especially both PVA and BW are added to the coating composition, the TSS was further higher. This is because PVA could increase mechanical properties of film that leads to the higher storage ability of Fib-Chi film. In addition, BW is hydrophobic and could reduce moisture loss of longan by evaporation.

3.2.6 Influence of coating composition on total acid content

TA contents decreased significantly during storage time in control fruits but more slowly (Fig. 5b) in fruits coated with the fibroin, chitosan, and Fib-Chi films. Similar results were also reported, chitosan coating produced a small

change in TA concentration throughout storage, and chitosan/ nano-silica composite had a more efficiency in delaying the TA decline regardless of the storage time (Jiang et al.,2020). PVA and BW additives contribute to delay the decrease in TA contents in fruits coated with Fib-Chi-PVA and Fib-Chi-BW films. When a combination of both PVA and beeswax in Fib-Chi-PVA-BW film is, the TA content of coated longans retained highest. Interestingly, up to 20 days, the TA content in the control sample decreased to 46% compared to the original while the acid content of fruit coated with composite film has remained about 91% after 40 days of storage. Postharvest longans treated with Fib-Chi-PVA-BW could retain the highest TA content.

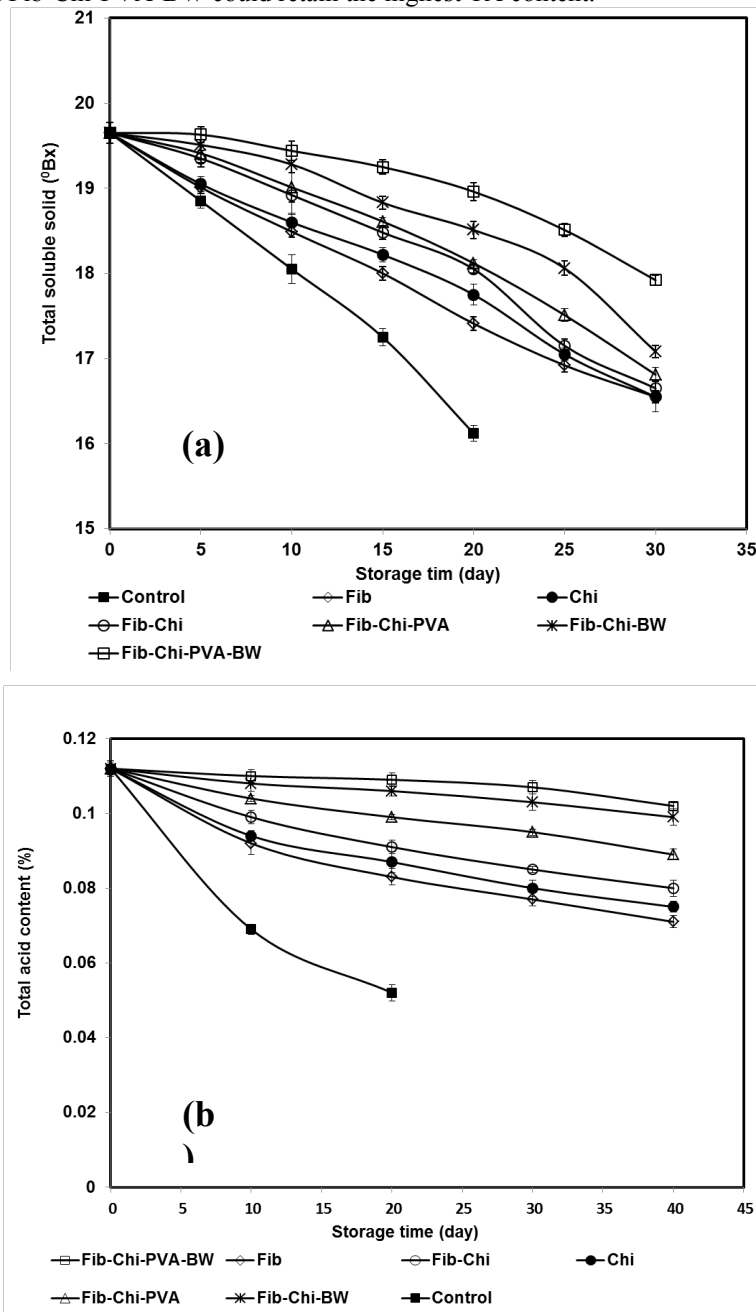


Fig. 5. Total soluble solid (°Bx) (a) and total acid (b) content of longan during storage.

3.2.7 Influence of coating composition on the vitamin C content

Vitamin C content decreased rapidly in the control sample, from 45.75 mg% to 39.42 mg% g after 10 days and to 28.8 mg% after 20 days of storage (Fig. 6) but decreased much more slowly in the preserved samples. Chi-Fib films have better preservation ability than chitosan and fibroin single films. After 20 days of storage, vitamin C contents in samples coated with chitosan, fibroin and Chi-Fib films were maintained in the levels of 38.38 mg%, 37.13 mg%, and 35.71 mg%, respectively. The addition of PVA and BW reduce the rate of spoilage, thus reducing the decomposition of vitamin C of the fruits; the Fib-Chi-PVA-BW sample has the best preservation ability. After 20 days, the vitamin C contents of fruits coating with Fib-Chi-PVA and Fib-Chi-BW films were 39.39 mg% and 40.47 mg%, respectively while vitamin C content in fruits coating with composite film was 41.97 mg%.

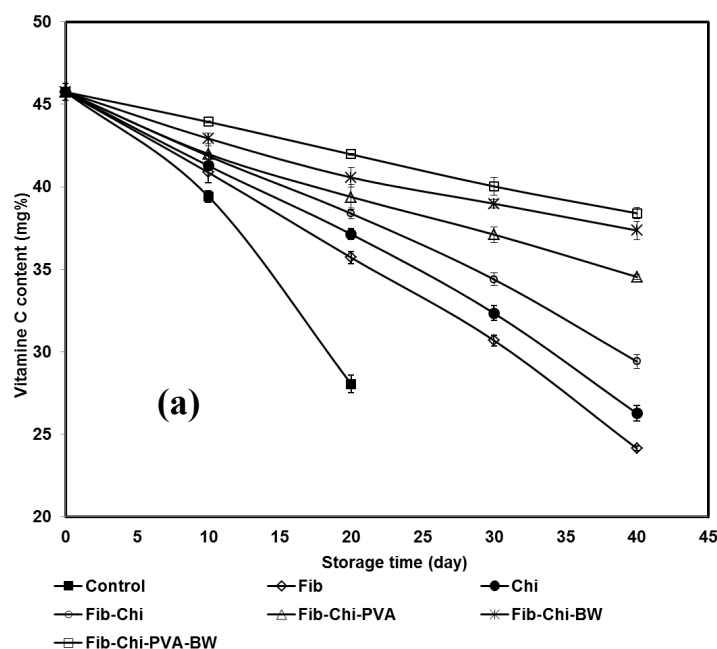


Fig. 6. Vitamin C content of longan during storage (mg%).

4. Conclusion

The properties of Fib-Chi membrane are better than those of single membranes because of chemical linkages between functional groups of chitosan and fibroin molecules. Addition of PVA to Fib-Chi membrane increases tensile stress at break of the membranes while addition of BW adjusts their water uptake. The fibroin, chitosan and Fib-Chi films can significantly prolong longan storage time, reduce browning index, retard weight loss and respiration and delay the quality reduction of fresh longan fruits. The addition of PVA and BW to Fib-Chi coating leads to a further increase in preservation ability. The condensation reactions between -OH groups of PVA and -OH, -NH₂ groups in chitosan and fibroin to enhance the tightness and durability of the films. In addition, the hydrophobicity of BW reduces moisture loss of fruits. Our results indicated that, Fib-Chi-PVA-BW films bring the highest protective effect among investigated films and can extend the shelf life of longan fruit up to 30 days during storage at 5°C. These results showed that the fibroin/chitosan coatings could provide an alternative approach for extending the storage-life of longans during postharvest storage. Storage studies at temperatures higher than 5°C need to be performed in further investigation in order to reduce the storage energy.

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