International Food Research Journal 29(6): 1439 - 1449 (December 2022)
Journal homepage: *http://www.ifrj.upm.edu.my*

Effects of chitosan and nano-SiO_2 concentrations on the quality of postharvest guavas (*Psidium guajava* L.)

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Article history

Received:
12 October 2021
Received in revised form:
16 March 2022
Accepted:
3 June 2022

Keywords

quality parameters,
guava fruits,
green storage,
chitosan and nano-SiO_2 concentrations

Abstract

Guava (*Psidium guajava* L.) is a perishable fruit susceptible to postharvest losses at tropical ambient temperature. Therefore, the development of green storage solution such as biodegradable film could be an alternative to increase guavas' shelf life. The primary objective of the present work was to explore the effects of combining chitosan and nano-SiO_2 coating at different concentrations on the external and internal quality parameters of guavas during 12-d storage at 15°C, and 8-d storage at 30°C. Weight loss, skin colour, firmness, ascorbic acid content, total soluble solids (TSS), decay incidence, and sensory taste score during storage were also analysed. Guavas coated with 2% chitosan and 0.02% nano-SiO_2 film were economically optimum to maintain the tested postharvest quality parameters, including better skin colour, higher TSS, fruit firmness, ascorbic acid content, and good taste scores, while keeping lower weight loss and decay incidence when compared with those of other treatments at both tested temperatures. Therefore, chitosan and nano-SiO_2 as a coating is a promising strategy for improving the postharvest quality of guavas.

DOI
https://doi.org/10.47836/ifrj.29.6.20

Introduction

Guava (*Psidium guajava* L.) belongs to the family Myrtaceae, and a popular tropical and climacteric fruit (Zahid *et al.*, 2019). Guava is commonly consumed worldwide in the form of fresh fruit or processed products, with distinctive sweet flavours and high nutritional value of dietary fibres, polyphenols, carotenoids, and ascorbic acid (Francisco *et al*., 2020). The ascorbic acid in guava is three to six times higher than in oranges, and its lycopene content is two times higher that of tomato (Uddin *et al*., 2002). In Vietnam, Taiwan guava variety is grown predominantly in the country's southern provinces due to its high quality and productivity, sweet taste, crispiness, and spongy attributes. According to the Food and Agriculture Organization (FAO, 2021), Vietnam has become one of the leading exporting countries of guava, with a rapid increase in both cultivating areas and yields of guava. However, guava has a short shelf life, and is a particularly perishable fruit (Hong *et al*., 2012; Francisco *et al*., 2020), which poses a massive challenge on postharvest preservation and long-distance transportation. Therefore, many researchers have recently focused on finding a promising method to retard postharvest decay of guava, where novel biological films could extend the quality and shelf life of many such fruits since they are safe, eco-friendly, low-cost, and easy to use (Nair *et al*., 2020).

In the preservation of guava, the biological film has been mainly comprised of starch, cellulose derivative, chitosan, chitin, protein, or fat (Nair *et al*., 2018; de Oliveira *et al*., 2020; Francisco *et al*., 2020; Galus *et al*., 2020; Domínguez-Espinosa *et al*., 2021). Among them, chitosan is a biological polymer with many desirable properties such as biodegradability, biocompatibility, safety, eco-friendliness, film-forming characteristics, and antibacterial ability (Lin *et al*., 2011), and has been applied in guava storage

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(Hong *et al*., 2012; Nair *et al.*, 2018; de Oliveira *et al*., 2020). Similarly, nano-SiO_2 has been successfully produced by sol-gel methods, and has many good mechanical properties such as safety, biocompatibility, biodegradability, chemical inertness, and environmental friendliness (Lai *et al*., 2006; Yu *et al*., 2012; Hassan *et al*., 2014; To *et al*., 2022); thus, it has been applied in many fields such as filler, pharmaceutical, medical, and food additive industries (FDA, 2011; Rahman and Padavettan, 2012), and to improve plant productivity (Hafez *et al*., 2021) and reduce water loss in plants (Alsaeedi *et al*., 2019). However, chitosan has high degree of brittleness, and low tensile strength and elasticity, thus limiting its preservation capacity for food application (Yeh *et al*., 2007; Sun *et al*., 2016). As noted by many earlier researchers, blending chitosan with other materials like nano-SiO_2 could improve the film-forming properties, mechanical properties, and bioactivity; thus enhancing its permeability (Shi *et al*., 2013; Sun *et al*., 2016) and antimicrobial capacity (Dhanasingh *et al*., 2011), inhibiting decay and disease on agricultural products (Yan *et al*., 2011), as well as enhancing the preservation ability of food (Sun *et al*., 2016) due to hydrogen-bonds and Si–O–C bonds in their structure. The combination between chitosan and nano-SiO_2 has been applied in storage fruits such as jujube (Yu *et al*., 2012; Kou *et al*., 2019), longan (Shi *et al*., 2013), loquat (Song *et al*., 2016), and fresh-cut cantaloupe (Sami *et al*., 2021) to reduce weight loss, colour changes and browning, limit decay, and enhance shelf life.

However, there is little information about the efficiency of guava storage applied with chitosan and nano-SiO_2 mixture that has been reported until now. Therefore, the present work was carried out to investigate the effect of film-forming solution at different concentrations of chitosan and nano-SiO_2 on the shelf life and quality of postharvest guavas during storage at 15 and 30°C.

Materials and methods

Preparation of guava fruits

Taiwan guava variety were harvested at mature green stage (75 days after flowers fully bloom) from a farm, after 5-year growth in Bau Bang district, Binh Duong province, Vietnam (11° 20’ 5’’N and 106° 38’ 19’’E). Harvested fruits were placed into boxes, transported within the same day to the laboratory, and the fruit stalk cut to about 1 cm in length. Damaged, diseased, mechanically injured, or fruits with signs of irregular ripening were excluded. Only fruits with uniform size and colour, with an individual weight of 300 ± 2 g were chosen. Before the experiments, fruits were washed under running water, disinfected by immersing in chlorinated water (150 ppm) for 5 min, rinsed with sterile distilled water, and then dried under a fan for 5 min. Thirty guavas were preliminarily tested for external and internal quality parameters before coating and storage.

Preparation of film-forming solution

Chitosan, extracted from shrimp (*Litopenaeus vannamei* Boone) shells (44.5 kDa average molecular weight, and ≥ 75% deacetylated degree), and nano-SiO_2 (20 nm) were purchased from the Research and Development Center for Radiation Technology (Vinagamma Center). Chitosan at concentrations 0, 1, and 2% (w/v) was dissolved in 0.5% acetic acid (v/v) (Merck, Germany), and nano-SiO_2 at concentrations 0, 0.02, and 0.06% (w/v) were then added and adjusted to pH 6 by 1 M NaOH, and stirred to obtain a homogenised mixture. The final mixture was further stirred (200 rpm, room temperature, 15 min) to evenly disperse nano-SiO_2 in the film forming solution. The concentrations of chitosan and nano-SiO_2 were based on previous studies of Hong *et al.* (2012) and To *et al*. (2022).

Experimental procedure

After drying, guavas were dipped in chitosan/nano-SiO_2 film-forming solution at different concentrations as listed in Table 1, while the control sample was treated only with distilled water.

Table 1. Experimental design.

Composition	Treatment (%)				
	Control	1	2	3	4
Chitosan	0	1	1	2	2
Nano-SiO_2	0	0.02	0.06	0.02	0.06

In triplicate, batches of 120 guavas were each coated with one of the five formulations, with one batch remaining uncoated as a control sample, as shown in Table 1. Every treatment was done by dipping ten fruits in 1 L of film-forming solution for 1 min. Treated fruits were then dried under a fan, placed into perforated cardboard boxes (40 × 25 × 20 cm, 10 fruit for each box), and stored at 15 ± 2 and 30 ± 2°C, respectively, at 80 ± 5% RH. Each treatment involved 12 boxes of guavas treated at the same

condition. The surveyed time interval was dependent on which experimental temperature used; 3, 6, 9, 12 d storage at 15°C, and 2, 4, 6, and 8 d storage at 30°C. The quality of guavas was tested for weight loss, skin colour, decay incidence, firmness, ascorbic acid, total soluble solid (TSS), and sensory quality (taste).

Fruit quality assessment

Weight loss of guavas was measured by analytical balance (UX420S, 420 g ± 0.01, Japan) according to Ding *et al*. (2006): weight loss (%) = [(initial weight – weight after storage time) / initial weight] × 100.

Skin colour (L*, a*, b*) was measured by a chromameter (CR400, Minolta Camera Co. Ltd., Osaka, Japan).

Decay incidence was measured as: (number of decayed guavas / total number of guavas) × 100.

Firmness was measured as expressed in Newton force (N) by Landtek FHT-15 fruit hardness tester with 3.5 mm tip (Guangzhou Landtek Instrument Co. Ltd., China).

Total soluble solid (TSS) was measured in % using a digital refractometer (Atago, Tokyo, Japan) for crushed fruit flesh.

Taste was measured by 10 trained panellists based on a nine-point scale (9 = excellent, 7 = good, 5 = acceptable but with limited marketability, 3 = poor, and 1 = extremely poor). All fruit quality assessments were measured with 10 guavas per treatment. Guavas in each treatment were presented in separate, randomly numbered trays to panellists. Each panellist evaluated three guavas per treatment.

Ascorbic acid was measured according to Gliszczynska-Swiglo and Tyrakowska (2003). Briefly, 0.5 mL of guava juice was prepared, added with 0.5 mL of 10% metaphosphoric acid (MPA) solution to obtain the final solution, then homogenised by vortex (5 min) and centrifugation (10,000 rpm, 5 min). Finally, the supernatant was injected into the high-performance liquid chromatography (HPLC) system comprising Waters 600 HPLC equipment (Waters corp., Milford, MA, USA) equipped with LiChrosorb C_{18} (250 × 4.0 mm, 5 mm; Merck KGaA, Germany) fitted with the same column guard. A gradient of mobile phase containing methanol (solvent A) and 5 mmol/L KH_2PO_4, pH 2.65 (solvent B) was used as follows: linear increment starting with 5 - 22% A in 6 min, and then return to the initial conditions within the next 9 min with the flow rate of 1.0 mL/min. The eluate was detected using a Waters 996 photodiode array detector set at 245 nm. Ascorbic acid content was determined based on UV spectrum and retention time with standard substrate, and expressed as mg/100 g FW.

Statistical analysis

All data were analysed and presented as mean and standard deviations using JMP 10.0 software (SAS Institute Inc., Cary, NC, USA). The experiment was designed following a completely randomised factorial design with one factor.

Results and discussion

Changes in weight loss

Results indicated that the weight loss percentage of all treatments progressively increased during storage at 15°C (Figure 1a) and 30°C (Figure 1b).

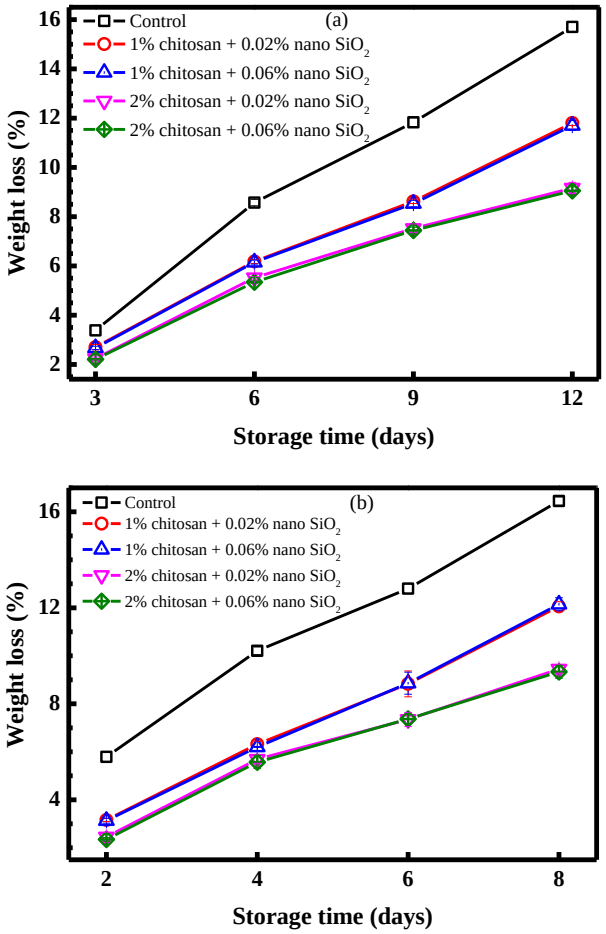

Figure 1. Effects of chitosan and nano-SiO_2 concentrations on weight loss at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates (n = 3).

Uncoated guavas obviously had a higher weight loss rate than those coated with chitosan and nano-SiO_2, in which concentration of film-forming solution showed an inverse ratio for the weight loss of coated guavas. During storage, the weight loss of guavas at 30°C was generally higher as compared to that at 15°C, due to higher temperature resulting in higher respiration processes, and consequently more significant water loss of guavas. Weight loss percentage was significantly lower in all treatments when compared to the control sample; the greatest weight losses were 15.7% after 12 d of storage at 15°C, and 16.45% after 8 d of storage at 30°C. The lowest weight loss ratio was observed in guavas treated with 2% chitosan and 0.06% nano-SiO_2 (9.05% after 12 d at 15°C and 9.33% after 8 d at 30°C). Guavas coated with 2% chitosan and 0.02% nano-SiO_2 exhibited insignificant difference in weight loss percentages, which were 9.16% after 12 d at 15°C, and 9.45% after 8 d at 30°C when compared with treatment of 2% chitosan and 0.06% nano-SiO_2. Therefore, the treatment with 2% chitosan and 0.02% nano-SiO_2 could be an economic solution to prevent weight loss in guava preservation.

These results agreed with Shi *et al*. (2013) who indicated that coating with chitosan/nano-SiO_2 had reduced the weight loss of longan fruits. Kassem *et al.* (2022) also confirmed the lower loss of 4.16% after 5 d of 'Tommy Atkins' mango at 20°C with the treatment of 2% chitosan + 1% nano-SiO_2 when compared with the other treatments. Generally, water loss in fresh fruits and vegetables are closely related to respiration processes (Zhu *et al*., 2008), which is considered the main cause leading to weight loss, turgor loss, and lower crispiness (Yang *et al*., 2014). Water loss above 5% is considered a tremendous loss of quality and economic value where fruits would become soft and shrivelled, thus significantly affecting consumer acceptability (Vitón *et al*., 2020). In uncoated guavas, transpiration and respiration rates combined with the physiological metabolism are high, thus resulting in high weight loss and fruit shrivelling (Lufu *et al*., 2020). The difference between uncoated and coated guavas in chitosan and nano-SiO_2 concentrations is shown in Figures 1a and 1b which indicated that guavas coated with chitosan/nano-SiO_2 were much more suitable for storage. Combining chitosan and nano-SiO_2 could improve material properties such as the porous structure, water vapour permeability, dissolving, diffusing, and gas evaporation due to forming hydrogen-bonds and Si–O–C bonds in the film-forming structure (Lai *et al*., 2006; Yeh *et al*., 2007; Dhanasingh *et al*., 2011; Shi *et al*., 2013; Sun *et al*., 2016).

Changes in skin colour

Chitosan and nano-SiO_2 concentrations significantly affected L*, a*, and b* values during storage of guavas at 15 and 30°C, as shown in Figures 2a and 2b, respectively. Generally, L* and b* values progressively increased during storage at both temperatures; however, a* value progressively decreased, and the skin of guavas turned from green to yellow. At 15°C, the degradation of skin colour was slower than that at 30°C due to ripening, physiological, and biochemical processes of the fruits at low temperature occurring more slowly. Chitosan and nano-SiO_2 concentrations had an inverse effect with changes in skin colour. Control guavas had greater changes than the other treatments for the same assessment time; after 4 and 6 d of storage at 30 and 15°C, respectively, skin colour turned to yellowish, thus indicating over-ripening or senescence, as guavas' carotenoid content progressively increased (Jain *et al*., 2003). The findings demonstrated that all treatments resulted in the retention of a darker fruit skin colour as compared to control guavas. Specifically, guavas coated with chitosan/nano-SiO_2 maintained a greenish yellow after 6 d at 30°C, and 9 d at 15°C, with 2% chitosan and 0.06% nano-SiO_2 retained a darker skin colour. Among all treatments, 2% chitosan and 0.02% nano-SiO_2 displayed the similar colour retention index with 2% chitosan and 0.06% nano-SiO_2 without a significant difference ($p > 0.05$).

Guava belongs to the climacteric respiration group, hence during ripening, respiratory rate and ethylene production would gradually increase, resulting in faster colour and biochemical changes during storage. The retention of a darker skin colour of chitosan combined with nano-SiO_2 coated guavas was due to synergistic effects of slowing colour pigment degradation of the pulp tissues on those coated guavas leading to a decrease in respiration, thus slowing down the metabolic and enzymatic activities of chlorophyllase, chlorophyll oxidase, and peroxidase in guavas during storage (Ranganna,1986). Similar results were reported in mango preservation using chitosan film with nano-SiO_2 (Kassem *et al.*, 2022), in jujubes (Yu *et al*., 2012), and in loquats (Song *et al*., 2016).

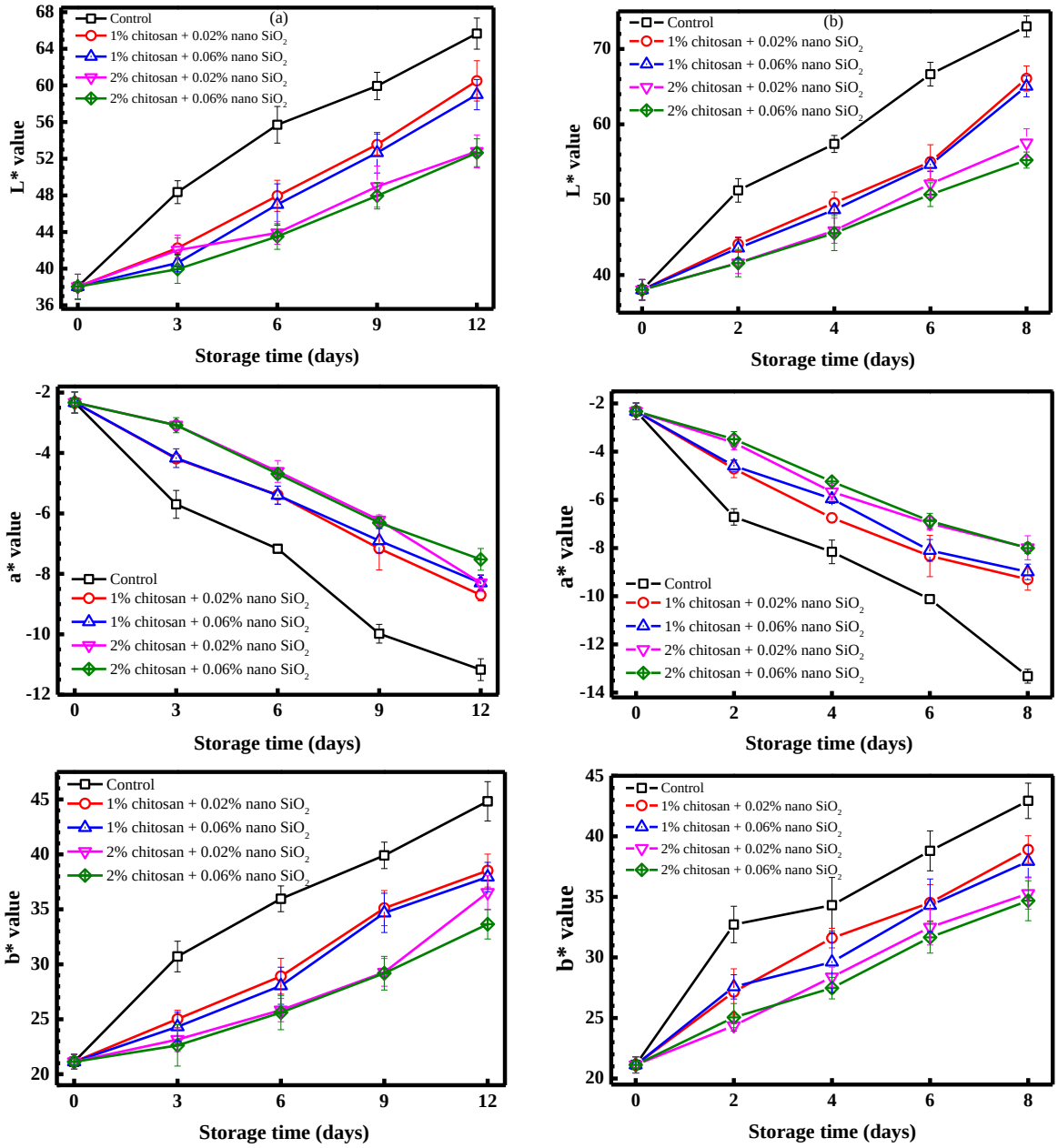

Figure 2. Effects of chitosan and nano-SiO_2 concentrations on skin colour at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates (n = 3).

Changes in firmness

Together with weight and colour changes, the structure of guavas was also altered with ripening processes, as noted in Figure 3. The firmness of guavas gradually decreased during the storage in all treatments at both storage temperatures. The decrease in firmness in control guavas was faster than in other treatments, and the firmness of guavas during the storage at 15°C showed a slower decrease than that at 30°C. After 4 and 6 d of storage at both temperatures, control guavas' firmness dramatically decreased, reaching the lowest value at the end of storage. 2% chitosan and 0.02% nano-SiO_2 was the lowest film-forming concentration that could maintain the firmness of guavas at both storage temperatures; no significant difference was found in firmness when compared with 2% chitosan plus 0.06% nano-SiO_2 (p > 0.05). The firmness values at both concentrations were 0.15 and 0.14 N after 12 d at 15°C, and 8 d at 30°C, respectively.

The decrease in firmness of guavas during storage at all the treatments at both temperatures could have been due to increased activity of polygalacturonase, β-D-glucosidase, and pectinesterase enzymes, from which undissolved pectin in the cell wall was disintegrated, thus

weakening the binding abilities between the cell and tissues, leading to softer skin and increased membrane permeability (Braga *et al*., 2018; Moreira *et al*., 2022). In addition, flesh firmness was altered due to starch being hydrolysed to glucose under enzyme α, β amylase action, thus also resulting in softening of the fruit (Pinto *et al*., 2013). Guavas were harvested at a mature biological stage with crisp structure and high firmness, but depending on the storage time, guavas became over-ripen until the senescence stage, thus resulting in protein dissolution of the films, weak binding of the structure, and firmness reduction of guavas. The result of guavas' firmness in the present work were similar with 'Tommy Atkins' mango dipped in the film-forming solution of chitosan and nano-SiO_2 (Kassem *et al.*, 2022). Therefore, chitosan combined with nano-SiO_2 in the present work could be considered in delaying biological ripening processes and reducing the fruit's softness, so that firmness of coated fruits could be better maintained.

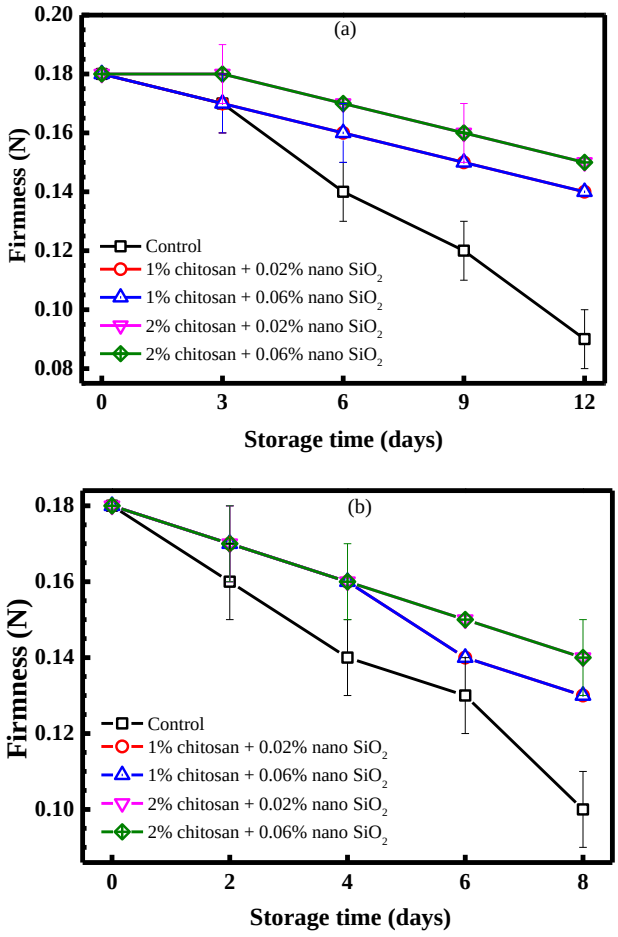

Figure 3. Effects of chitosan and nano-SiO_2 concentrations on firmness at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates (n = 3).

Changes in ascorbic acid content

The ascorbic acid contents of postharvest guavas at both temperatures were remarkably altered by chitosan and nano-SiO_2 concentrations, as shown in Figure 4.

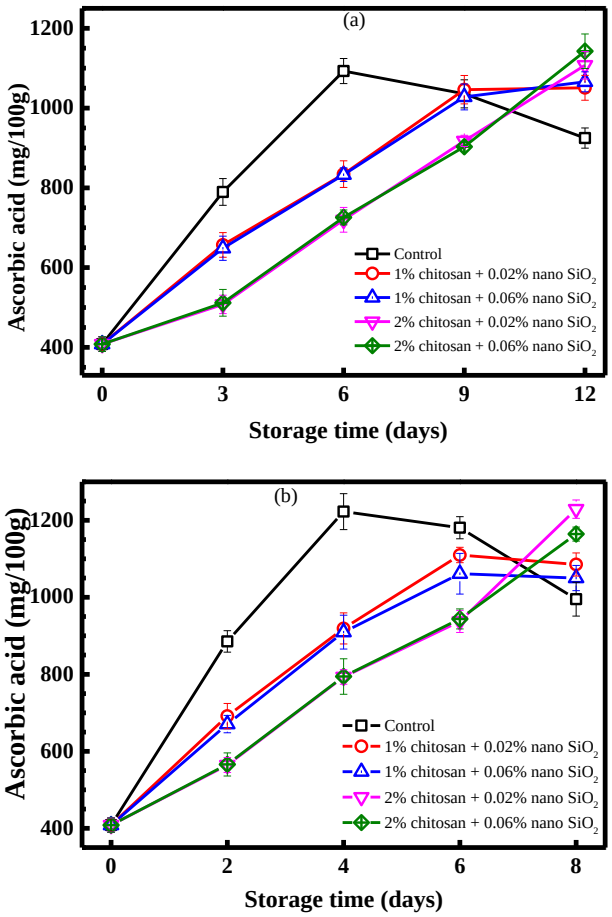

Figure 4. Effects of chitosan and nano-SiO_2 concentrations on ascorbic acid content at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates (n = 3).

The ascorbic acid content of control guavas started increasing after 6 d at 15°C, and 4 d at 30°C during storage, and decreased afterward. The concentration of 2% chitosan and 0.02% nano-SiO_2 achieved more effectiveness during storage than other treatments, with no significant difference with 2% chitosan and 0.06% nano-SiO_2, where the ascorbic acid content gradually increased during storage at both temperatures. Ascorbic acid is a vital nutrient component, but easily degraded due to oxidation (Veltman *et al*., 2000) and respiration, which is closely related to the decrease in oxygen permeability of guava skin (Nair *et al*., 2018). These results agreed with previous studies which indicated that the ascorbic acid content of guavas would reach the

lowest value at ripeness stage 1 (mature green) and stage 2 (fruits start turning colour), reach the highest value at ripeness stage 3 (over-ripe), and then decrease at soft-ripe stage (El Bulk *et al*., 1997; Mercado-Silva *et al*., 1998). The difference between coated and uncoated guavas could have been due to respiration processes, ethylene production, senescence, and biological changes inside uncoated guavas that occurred faster. These results were consistent with weight loss, skin colour, and firmness of guavas described earlier; control guavas experienced higher and faster biological and respiratory activities than coated guavas, thus resulting in a more significant quality loss.

Changes in total soluble solid content

The TSS of guavas also changed during storage differently among treatments as shown in Figure 5. TSS of control guavas increased during the several initial days of storage, and reached the highest after 6 d at 15°C, and 4 d at 30°C, and then started to decrease. Remarkably, TSS of guavas coated with 2% chitosan and 0.02% nano-SiO_2 gradually increased during storage at both temperatures. The highest values of TSS were observed at the end of storage at 11.5 and 10.93%, for 15 and 30°C, respectively. The lowest TSS was observed in control guavas after 8 d of storage at 30°C (9.75%), and after 12 d of storage at 15°C (9.89%). These changes could have been due to starch being hydrolyse to sugar (Arthey and Philip, 2005) under enzyme α, β amylase action, thus leading to the increase in total sugar content, and therefore TSS also increased. TSS of guavas was from 7.95% at the harvest stage to 11.65% at the ripening stage. According to El Bulk *et al*. (1997), TSS was observed from 9 - 13%, and progressively increased throughout ripening, depending on cultivars. Mahajan *et al*. (2009) reported that TSS increased and reached the highest in the 15 d storage of 'Allahabad Safeda' guavas, and then decreased. The decrease in TSS during storage of guavas could have been related to respiration (Smith *et al*., 1979), thus resulting in sugar loss (Li *et al*., 2015) and senescence (Khan *et al*., 2016). The change in guavas coated with chitosan/nano-SiO_2 occurred slower than in control guavas due to reduced respiration and metabolic process, thus resulting in delayed senescence. TSS in longan fruits coated with chitosan/nano-SiO_2 was recorded as higher than the other samples; meanwhile, the lowest TSS was noted in the control fruits (Shi *et al*., 2013). In addition, Song *et al*. (2016) reported that the reduction in TSS of loquat fruit was delayed by chitosan/nano-SiO_2 coating. These results agreed with those obtained in the present work.

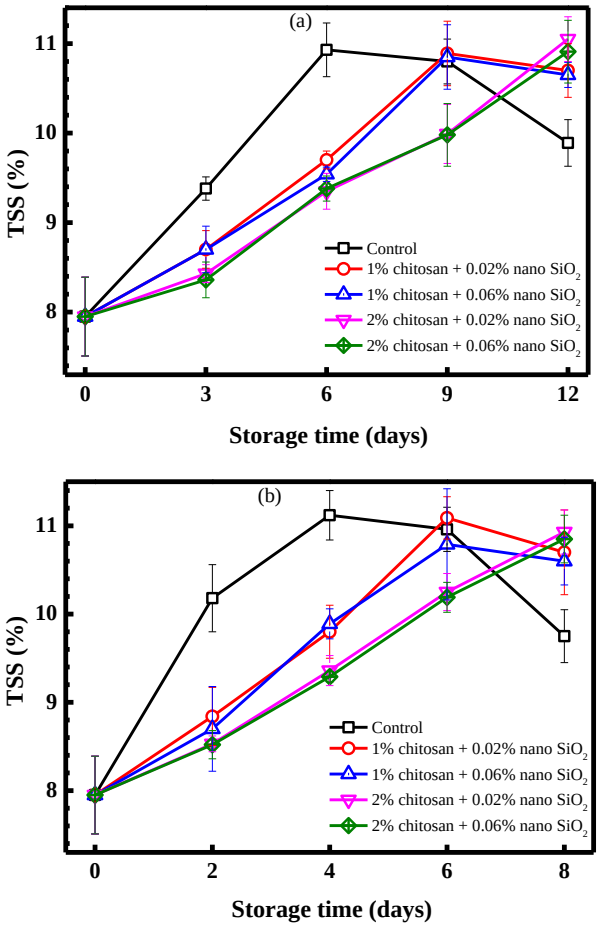

Figure 5. Effects of chitosan and nano-SiO_2 concentrations on total soluble solid at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates (n = 3).

Changes in decay incidence

The primary cause of postharvest guava decay incidence might be bacterial and fungal infection during guava storage. However, in the present work, this was delayed by the coating with chitosan and nano-SiO_2, as shown in Figure 6. The concentration of chitosan and nano-SiO_2 was inversely proportional to decay incidence of guavas. Decay incidence of guavas stored at 15°C was lower than at 30°C, as was also reported by Hong *et al*. (2012). In the first initial of 3 d of storage at 15°C, guavas did not display any decay at all treatments, whereas control guavas had already started to show signs of decay. Besides that, for control guavas at 30°C, they began to show a sign of deterioration after 2 d storage (6.94%), which increased throughout storage time. Furthermore, control guavas had the highest decay incidence

percentage (27.03% at 15°C and 40.06% at 30°C). Guavas treated with 2% chitosan and 0.06% nano-SiO_2 indicated the lowest decay incidence of 0.66 and 14.92% by the end of storage, at 15 and 30°C, respectively. However, these results were not significantly different ($p > 0.05$) from coating with 2% chitosan and 0.02% nano-SiO_2 of 2.31% (15°C) and 14.6% (30°C). Therefore, 2% chitosan and 0.02% nano-SiO_2 could be selected to prevent decay incidence in postharvest guavas. A combination of chitosan with nano-SiO_2 could further enhance the antimicrobial ability of the films (Dhanasingh *et al*., 2011), and inhibit disease on agricultural products (Yan *et al*., 2011). These results agreed with Yu *et al*. (2012) who indicated that chitosan combined with nano-SiO_2 could enhance the shelf life of jujubes by improving skin colour and reducing decay incidence and weight loss. Moreover, Tian *et al*. (2019) also reported that the significant decrease in the decay rate of ginkgo (*Ginkgo biloba* L.) seeds was achieved by incorporating chitosan and nano-SiO_2 coating.

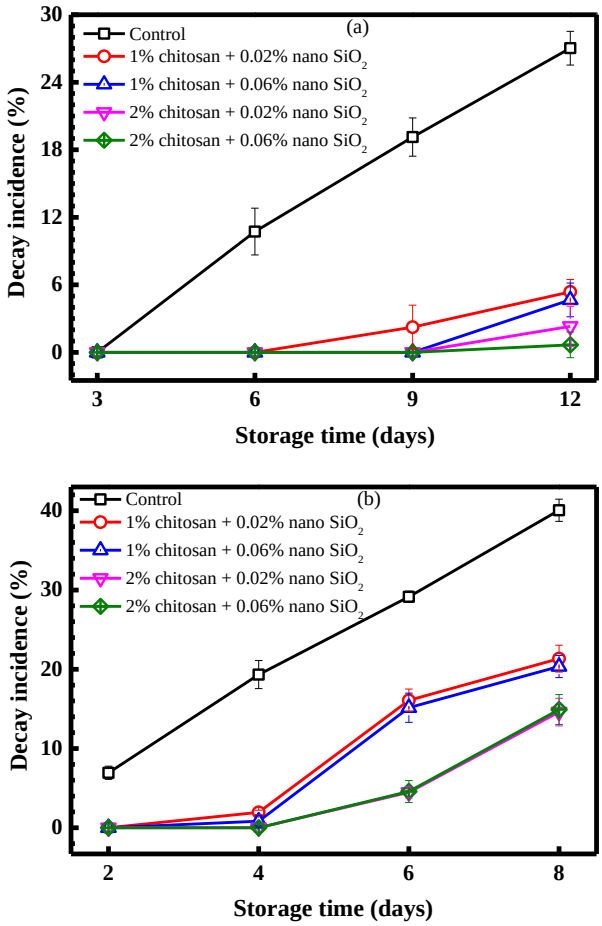

Figure 6. Effects of chitosan and nano-SiO_2 concentrations on decay incidence at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates ($n = 3$).

Sensory quality (taste) during storage

The taste of guavas showed a gradual decrease during storage at both temperatures, as shown in Figure 7.

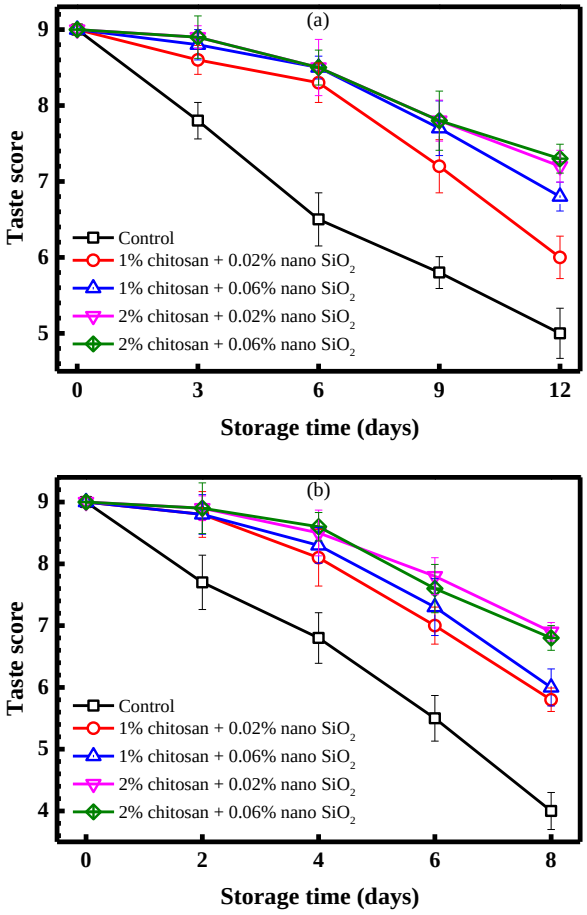

Figure 7. Effects of chitosan and nano-SiO_2 concentrations on taste score at **(a)** 15°C, and **(b)** 30°C of guava fruits during storage. Data are mean ± standard deviation of triplicates ($n = 3$).

In particular, the decrease in taste was more rapid at the end of storage. During storage, the minimum taste score was associated with the control guavas (after 8 and 12 d, with taste scoring 4.0 and 5.0, at 30 and 15°C, respectively) as compared to all treatments. This could have been due to higher water loss and biological changes of the control guavas, thus resulting in higher decay incidence and changes in skin colour, TSS, ascorbic acid, and consequently, a lowered sensory score. In addition, the sensory taste score was maintained at a higher rate for the coated guavas. It was noticed that guavas coated with 2% chitosan + 0.02% nano-SiO_2, and 2% chitosan + 0.06% nano-SiO_2 each held a maximum score for tasting of 6.9 after 8 d at 30°C, and 7.3 after 12 d at 15°C, respectively (Figure 7). In general, throughout

the storage period of 12 d at 15°C and 8 d at 30°C, the film-forming solution containing 2% chitosan and 0.02% nano-SiO_2 exhibited better sensory quality attribute and a favourable taste score among all the treatments, on par with the 2% chitosan film with 0.06% nano-SiO_2. A similar trend was also observed in the research of Kassem *et al*. (2022), although with a more condensed coating formulation of 2% chitosan plus 1% nano-SiO_2, that the overall fruit sensory attributes of mango fruits such as appearance, colour, texture, taste, flavour, and overall acceptability was best retained.

Overall, the film-forming formulation of 2% chitosan performed better than that of 1% chitosan, regardless of the nano-SiO_2. The nano-SiO_2 differed between 0.02 and 0.06% in skin colour, ascorbic acid, TSS, decay incidence, and taste parameters. However, for weight loss and firmness, there was no difference between 0.02 and 0.06% of nano-SiO_2 for the film-forming solution.

Conclusion

The present work demonstrated that chitosan and nano-SiO_2 were more effective in maintaining the quality of guavas during storage at 15 and 30°C. The combination using 2% chitosan with 0.02% nano-SiO_2 was desirable for better preservative efficacy, which maintained the best quality parameters of guavas with fewer changes in weight loss, skin colour, firmness, ascorbic acid content, and TSS during storage. In addition, this edible film also showed lower decay incidence, and higher taste rating than control fruit up to the final day of storage. Data analytics indicated that guava fruits coated with 2% chitosan + 0.02% nano-SiO_2 could be applied to prolong preservation, maintain quality, and reduce guavas' decay.

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