Effectiveness of a composite edible coating on the post-harvest conservation of guava (*Psidium guajava L*)

Hitihami Mudiyanselage Kumuduni Lakmali and Chamila V.L. Jayasinghe*

Department of Food Science and Technology,
Faculty of Livestock, Fisheries and Nutrition,
Wayamba University of Sri Lanka, Sri Lanka
Email: kumudunilakmali63@gmail.com
Email: cjayasinghe@wyb.ac.lk
*Corresponding author

Jayasinghe Mudalige Jagath K. Jayasinghe

Department of Food Science and Technology,
Faculty of Applied Sciences,
University of Sri Jayawardanapura,
Nugegoda, Sri Lanka
Email: jcy6199@yahoo.com

Abstract: Guava is a climacteric fruit that ripens rapidly and is highly perishable. Locally grown guava is marketed without receiving any treatment for shelf life extension, resulting in the wilting and withering of fruits. This study aimed to evaluate the effectiveness of a thin edible coating developed as a water-based filmogenic solution containing different concentrations of beeswax, tamarind seed powder (TSP), sunflower oil, and surfactant to enhance the post-harvest shelf life of guava. The bio polymeric film containing 0.05% TSP, 1% beeswax, and 5.5% sunflower oil presented the best results, and a 6 s dipping time resulted in the best polymeric network formation, which minimised water loss and improved the appearance of guava. The results indicated that a thin natural bio polymeric coating conserves the post-harvest shelf life of giant guava for 13 days at tropical ambient temperature (30 ± 2°C) and 21 days at regulated temperature (25 ± 1°C).

Keywords: beeswax; guava; natural bio polymeric coating; sensory attributes; tamarind seed powder; TSP.

Reference to this paper should be made as follows: Lakmali, H.M.K., Jayasinghe, C.V.L. and Jayasinghe, J.M.J.K. (2019) 'Effectiveness of a composite edible coating on the post-harvest conservation of guava (*Psidium guajava L*)', *Int. J. Postharvest Technology and Innovation*, Vol. 6, No. 4, pp.314-329.

Biographical notes: Hitihami Mudiyanselage Kumuduni Lakmali received her BSc in Food Science and Nutrition from the Wayamba University of Sri Lanka. She is currently undergoing her MSc in Plant Biology at the Laval University, Quebec, Canada. She carried out several projects at the Wayamba University in developing functional Kirala jam-group project in 2015 and developing a HACCP plan for a virgin coconut oil processing company in Sri Lanka-group project in 2015.

Chamila V.L. Jayasinghe is a Professor of Food Science and Technology, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, where she has been a faculty member since 2004. She is an Adjunct Professor of the Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam, India since 2018. She completed her Master of Philosophy degree in Food Chemistry from University of Sri Jeyawardanapura, Sri Lanka and her PhD in Food Science and Technology at the Tokyo University of Marine Science and Technology, Japan in 2003. Her research interests are reducing post-harvest losses, functional foods, food safety and food innovations.

Jayasinghe Mudalige Jagath K. Jayasinghe is a senior faculty member of the Department of Food Science and Technology, University of Sri Jayewardenepura. Before joining to the university he served as an Economist and Senior Program Manager of livelihood development projects and he has experience on post-harvest management of fruit and vegetables especially for the export market. He obtained his PhD in Management and Economics in Agriculture and Forestry from the Tokyo University of Agriculture and Technology, Japan. His research interests include food marketing, consumer behaviour analysis and post-harvest management of fruit and vegetables.

1 Introduction

Guava kept without any treatment at ambient conditions may deteriorate due to the loss of water from the fruit surface, a faster respiration rate, and the attack of microorganisms due to the lack of hard skin (Zahid et al., 2011). The shelf life of harvested fruits and vegetables can be extended by taking implementing several effective measures, including temperature reduction, modified atmosphere packaging, irradiation and application of coatings (Jianglian, 2013). Most fruits and vegetables possess a natural waxy layer on their surface known as the cuticle, which generally presents low permeability to water vapour (Oliveira et al., 2018). The application of an external coating is an effective method for extending the post-harvest shelf life of fruits, as it can replace the natural waxes that are removed during washing and post-harvest handling (Khorram et al., 2017) (Lin and Zhao, 2007).

Coatings with selective permeability to gases are capable of decreasing the interchange of O_2 and CO_2 between coated fruits and the environment, which results in a high CO_2 concentration within fruit tissues and delays ripening by reducing the synthesis of ethylene (Galgano, 2015; Kim et al., 2015). Thus, the coating of fruits is a promising solution for extending the post-harvest shelf life of fresh commodities, as the coating itself can create a semipermeable barrier while carrying an antioxidant and antimicrobial agent that further supports the retardation of fruit spoilage (Nawab et al., 2017; Oliveira et al., 2018). In addition, the coating acts as primary packaging, which improves the mechanical properties, sensory perception, and microbial protection of fruit, thereby prolonging its shelf life (Galus and Kadzińska, 2015).

Guava is the most nutritious and healthful fruit grown in the tropics and subtropics of the world and is referred to as a ‘super fruit’. It is rich in minerals such as calcium, magnesium, iron, zinc, potassium and phosphorus; vitamins such as thiamine, niacin, folate, riboflavin, and vitamins C, K, and A; and dietary fibre (Murmu and Mishra, 2018; Anon, 2014). It is low in calories (68 kcal/100 g) and rich in antioxidative polyphenol compounds (García-Betanzos et al., 2017). Guava reduces serum cholesterol and hypertension. Guava is used in the treatment of gastrointestinal-related problems, particularly dysentery, gastric insufficiency, laryngitis, swollen mouth, sore throat and ulcers (Anon, 2014; Mangaraj et al., 2014).

Guava exhibits a climacteric nature, ripens rapidly, is highly perishable, and exhibits wilting and shrivelling within 3–4 days of ripening (Abreu et al., 2012). Lipids, proteins, and carbohydrate or polysaccharide compounds may use alone or in several composite formulations as ingredients for creating an edible coating that acts as an excellent barrier to moisture loss due to their hydrophobic properties (Oliveira et al., 2018; Jianglian, 2013; Yusof et al., 2019). In the aspect of eco-friendly, nowadays world is moving towards biodegradable natural non-toxic coatings other than synthetic forms of edible coating (González-Reza et al., 2018).

The study mainly focuses on developing a bio polymeric film from composite mixture of beeswax, TSP, and sunflower oil, accessible in tropical region in forming an edible coating with higher barrier properties for moisture. Beeswax is a complex of lipid mixture compost of saturated and unsaturated linear and complex monoesters and is commonly used in mixtures of composite coating. It naturally consists of pollens that provide antioxidative and antimicrobial properties for the coating (Oliveira et al., 2018; Fratini et al., 2016). TSP itself is a mixture of considerable amount of starch, essential oils and a rich source of phytochemicals which possesses antimicrobial activity (Vijay, 2013). Sun flower oil is a low cost, non-toxic and non-volatile source of mono-unsaturated and polyunsaturated fats with low levels of saturated fats, and is associated with various positive health benefits in food products (Galus and Kadzińska, 2015).

Most of the researches focused on applying of beeswax-based edible films and coatings to preserve fruits and vegetables and no or less experiments are on the impact of TSP with high antioxidant and antimicrobial properties in fruit coatings. Incorporation of TSP with sunflower oil and beeswax has preserved guava fruit for two weeks at room temperature due to its anti-microbial and anti-oxidative properties. Furthermore, few number of researches have been conducted on applying an edible coating on giant guava which is susceptible to quick deterioration and browning at room temperature and are commonly available in the dry zone of Sri Lanka. Mixing of a minor amount of natural ingredients and minimising the dipping time in filmogenic solution had reduced the thickness of the coating. The effectiveness of coating in extending the post-harvest shelf life of giant guava at tropical ambient temperature (30 ± 2°C) and regulated temperature (25 ± 1°C) was evaluated. This low cost and easily applicable technology will be beneficial to both giant guava producers and retailers to reduce post-harvest losses of giant guava and get good market price while providing a high-quality and satisfactory product for consumers.

2 Materials and methodology

2.1 Sampling

Samples of guava fruits (*Psidium guajava L*) were obtained from a farmer in Norochcholei, Puttalam district, North Western Province, Sri Lanka. Maturity index 2 guava fruit were carefully selected for uniformity of size (375–405 g), shape, and colour and an absence of injuries. The fruits were wrapped separately in paper, packed in wooden boxes and transported to the laboratory.

2.2 Pretreatment of guava fruits

Pretreatment of fruit was performed according to Ruzaina et al. (2013). The fruits were washed with 0.5% potassium sorbate for disinfection and then rinsed with water. After rinsing, the fruits were blotted dry with sterilised paper towels and left to dry at room temperature (30 ± 2°C).

2.3 Preparation of tamarind seed powder (TSP)

Preparation of tamarind (*Tamarindus indica*) seed powder with preserved antimicrobial activity was performed according to the method described by Natukunda et al. (2016). Tamarind seeds were soaked overnight in water (1:3 w/v) and washed using distilled water. The cleaned seeds were air-dried for 14 days. TSP was prepared by using a grinder (Jaipan MC4043, India). The powder was sieved through a 250 µm mesh and stored in an airtight container in a freezer at –18 ± 2°C before use.

2.4 Selection of the most effective proportions of TSP and beeswax for the coating mixture

The amounts of TSP and beeswax included in the coating were evaluated using three levels of TSP [0.05%, 0.1%, 0.15% (w/v)] and three levels of beeswax [1%, 2%, 3% (w/v)] dissolved in 100 mL of distilled water. Through a sensory evaluation, the proportions of TSP and beeswax that resulted in the highest consumer appeal were chosen.

2.5 Selection of the most effective proportion of sunflower oil and dipping time in the coating solution

The effectiveness of the water-based coating mixture was evaluated with three levels of sun-flower oil: 3.5%, 4.5%, and 5.5% (v/v) with a mixture of other ingredients, including 0.05% (w/v) TSP, 0.5% (v/v) emulsifier (Tween 80) and 1% (w/v) beeswax. The ingredients were mixed using a magnetic stirrer while increasing the temperature to 90 ± 1°C, and after mixing, the solution was cooled down to 68 ± 1°C. Guava fruit were dipped in the prepared coating solution for 2 s and allowed to dry at room temperature, after which the quality evaluation was conducted by comparison with uncoated guava.

According to the results of previous experiments, 5.5% (v/v) sunflower oil with 0.05% (w/v) TSP, 0.5% (v/v) emulsifier (Tween 80) and 1% (w/v) beeswax was selected as the best composition for the water-based emulsion. Subsequently, the solution prepared with all other ingredients in a similar manner was tested with different dipping times of 2 s (treatment A), 4 s (treatment B), and 6 s (treatment C). The quality of the treated guava was compared with uncoated guava. The coating pick-up was determined according to the method described by Zahid et al. (2011), and the coating properties resulting from the best treatment were evaluated at 25 ± 1°C (regulated temperature) and 30 ± 2°C (room temperature).

2.6 Quality analysis

The weight loss percentage of guava was determined by measuring the difference between the initial and final weights according to the method described by Shahid and Abbasi (2011). All analyses were conducted with three replicates, and the average value was obtained for each test. The pH was measured using a standard calibrated pH metre (OHAUS-USA), which was calibrated to pH 4.0 and 7.0 using standard solutions [AOAC (1990) standard method]. Titratable acidity was determined according to the AOAC (1990) titrimetric method. Briefly, guava samples were blended, and their juice was obtained by filtering through a muslin cloth. One millilitre of juice was diluted with 9 mL of distilled water, titratable acidity was determined by titration with 0.1 M NaOH in the presence of phenolphthalein as an indicator, and the results were expressed as the % citric acid. Total soluble solids (TSS) were determined according to the method described by Abreu et al. (2012) using a hand refractometer (ATAGO-Japan) at room temperature.

The moisture content was determined by the standard AOAC (1990) method. The moisture-can was cooled in a desiccator, and its weight was determined. The weight of the empty cooled moisture-can was recorded as W_1. An approximately 2–5 g guava sample was weighed into the moisture-can. The weight of the moisture and food samples was recorded as (W_2). The moisture-can was then placed in an air-drying oven at 105°C (Memmert-USA) and dried to constant weight over at least 24 h. The moisture-can was removed, and it was cooled in a desiccator. The weight of the moisture-can with guava was recorded after drying (W_3). The drying process was repeated for an additional 30 minutes until successive weights differed by less than 0.1% of the original mass of the sample.

The total phenolic compound content in guava was determined according to the Folin-Ciocalteu procedure (Chandrasekara and Shahidi, 2010) with some modifications. Samples of 2 g of guava were ground, and 10 mL of methanol was added to a conical flask, which was covered with aluminium foil. The conical flasks were shaken at 175 rpm for 25 minutes at 60°C in a shaking water bath. The supernatant was transferred to an EDTA tube, followed by centrifugation at 4,000 g for 5 minutes. The supernatant was added to a 25 mL volumetric flask, which was then topped up with methanol. Approximately 0.5 mL of the above solution was added to a 10 mL volumetric flask. Approximately 3 mL of distilled water and 1 mL of Folin-Ciocalteu solution were added to each flask. The flasks were shaken thoroughly. These flasks were kept in the dark at room temperature for 7 minutes. To each flask, 2 mL of a standard sodium carbonate solution was added, followed by bringing the volume to 10 mL with distilled water. These samples were held for another 3 minutes in the dark at room temperature. The absorbance of the blue colour development was read at 765 nm using a UV visible spectrophotometer. Phenolic concentrations were determined by comparing the absorbance of the samples with standards of Gallic acid. The results were expressed as milligrams of Gallic acid in 100 g of guava peel.

The physical appearance of guava was checked from 12 megapixel images throughout the storage period.

2.7 Sensory evaluation

Sensory evaluation was conducted according to the method described by Singh-Ackbarali and Maharaj (2014) by 30 trained panellists to determine the rank of characteristic, such as the colour, appearance, taste, odour, texture and overall acceptability of the coated and uncoated guava. A five-point hedonic scale was used (1 – dislike very much, 2 – dislike moderately, 3 – neither like nor a dislike, 4 – like moderately and 5 – like very much). The results were analysed by the Friedman test, and the mean values were compared.

2.8 Microbial analysis

The antimicrobial efficiency of the coating was evaluated by the counting of filamentous fungi and yeast according to the method described by Soares et al. (2011) as follows. Samples of 25 g of a 0.5 cm thick peel were homogenised in 225 mL of peptonised water in sterile bags, and the mixture was agitated in a stomacher for 120 s. From the broth, subsequent dilutions were conducted for analysis via the spread plate method on potato dextrose agar (PDA). The results are presented in CFU g^{-1} of the peel.

2.9 Statistical analysis

A Friedman non-parametric test was used to analyse the sensory evaluation data. All experiments were carried out in triplicate, and the results were analysed by using SPSS 16 software. The effects of different coatings on guava over storage time were analysed by using a complete randomised design. The values were expressed as the mean ± standard deviation. Differences at $p < 0.05$ were considered to be significant.

3 Results and discussion

3.1 Effect of different proportions of TSP and beeswax on the consumer acceptability of guava

Fruit coating is the process of covering fruit with edible natural or artificial material. Edible surface coatings are used as a carrier of functional ingredients such as antioxidants and anti-microbial compounds. TSP and beeswax are under-utilised, inexpensive materials that are commonly available in tropical and subtropical countries. In this study, TSP was used as an ingredient in a coating mixture for the first time. The present study demonstrated the effectiveness of TSP as a component of a new biopolymeric coating mixture that extended the shelf life of guava with a significant reduction of microbial growth due to the antioxidant and antimicrobial activity possessed by TSP. The mean scores obtained for the appearance and overall acceptability of coated guava with changing percentages of TSP and beeswax are shown in Table 1. The combination of TSP and beeswax at a proportion of 0.05:1 (w/v) with 0.5% (v/v) Tween 80 as an emulsifier resulted in the highest mean rank for the appearance (85.50) and overall acceptability (85.33) of coated guava.

Table 1 Mean scores for the appearance and overall acceptability of coated guava

Treatment (TSP:BW (w/v)	*Mean rank for appearance*	*Mean rank for overall acceptability*
0.05:1	85.50[a]	85.33[a]
0.05:2	65.75[b]	67.68[b]
0.05:3	53.35[c]	56.80[c]
0.1:1	63.00[d]	59.25[d]
0.1:2	45.80[e]	43.80[e]
0.1:3	29.05[f]	31.00[f]
0.15:1	25.70[g]	24.60[g]
0.15:2	22.35[h]	24.60[g]
0.15:3	19.00[i]	18.20[h]

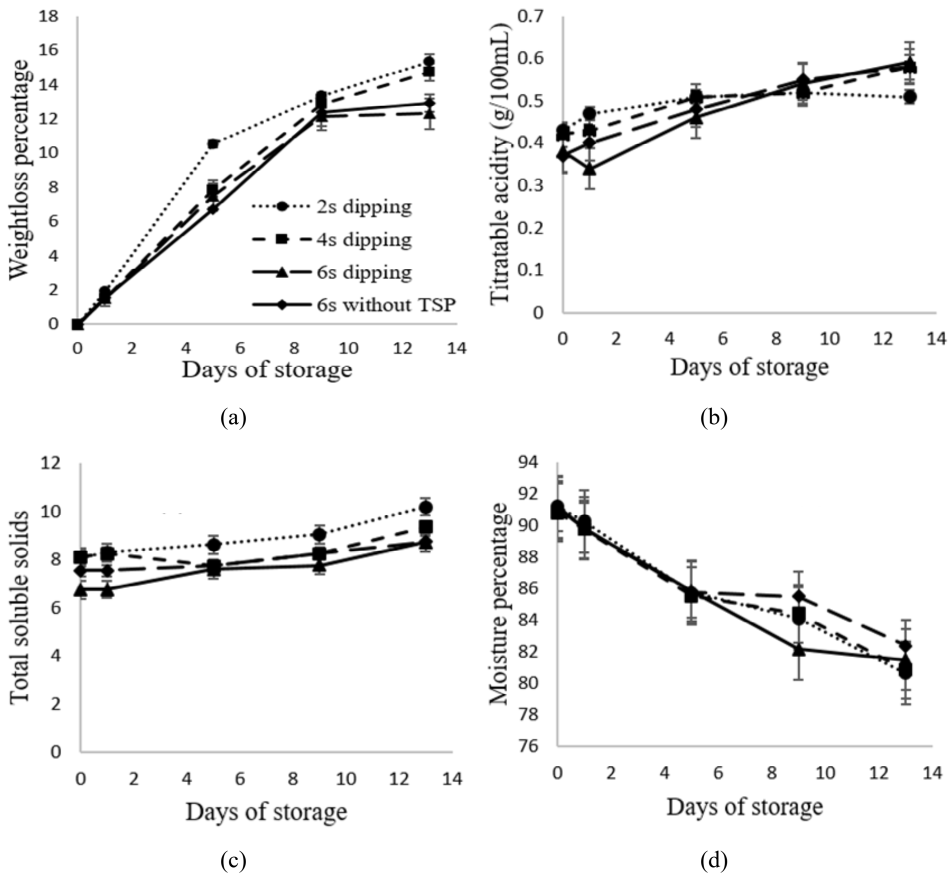
Notes: TSP: tamarind seed powder and BW; bees wax. Means within each column with different superscripts are significantly ($p < 0.05$) different.

In the present study, a minimal amount of (1%) beeswax was effectively used in the water-based coating mixture. Beeswax is a natural mixture of hydrocarbons, free fatty acids, monoesters/hydro-monoesters, complex wax esters and other natural residues such as propolis, pollen and small amounts of floral components. The results revealed that the mixture of edible natural ingredients used in this study might be highly compatible for the production of an effective coating mixture for guava. The thin coating used in this study did not reduce consumer appeal, which is usually due to the feeling of the wax layer in the mouth during consumption. Gum arabic and carnauba wax are commonly used in coating mixtures as plant-based waxings at a higher percentage (5%) (Murmu and Mishra, 2018) than the percentage we used in the present study.

3.2 Effect of changing the proportion of sunflower oil and dipping time in the coating solution on the shelf life of guava

Figure 1 shows the variation in the weight loss, titratable acidity, TSS content and moisture content of guava with variation of the dipping time in the coating solution. The weight loss percentage in guava dipped for 2 s increased from 1.88 to 15.35%, while for the 6 s dipped guava, it varied from 1.51 to 12.3% over 13 days of storage [Figure 1(a)]. The results revealed that weight loss was reduced with an increase in the dipping time in the coating solution to 6 s. A similar trend was observed for the variation of moisture content, which was decreased by 8.2% in 6 s dipped guava, while 2 s dipped guava showed a 10.67% decrease under the same conditions [Figure 1(d)]. A gradual increase in TSS was observed during the 13-day storage period regardless of the dipping time, as the difference in the TSS increment was 1.2 for the 6 s dipping time and 1.0 for the 2 s dipping time [Figure 1(c)]. Furthermore, there was no significant difference in titratable acidity with variation of the dipping time.

Figure 1 Variation of the weight loss %, (a) titratable acidity (b) TSS content (c) moisture content (d) guava with varying dipping times in the coating solution



The coating pick up indicates the weight of the coating layer applied on guava. The coating pick up was not significantly different ($p < 0.05$) between the treatments in which the content of sunflower oil and the dipping time were changed, as shown in Table 2. Accordingly, guava coated with 0.05% (w/v) TSP, 0.5% (v/v) Tween 80, 1% (w/v) beeswax and 5.5% (v/v) sunflower oil with a dipping time of 6 s was selected as the most effective coating for extending the shelf life of giant guava with maximum moisture barrier properties.

The weight loss percentage of guava under treatment C [coated with TSP 0.05% (w/v) Tween 80 0.5% (v/v), beeswax 1% (w/v) and sunflower oil 5.5% (v/v) with a 6 s dipping time in the coating solution] was minimal throughout the storage period compared with uncoated guava and guava coated with 3.5% sunflower oil (treatment A) or 4.5% sunflower oil (treatment B) along with other coating ingredients. The lowest TSS increment was recorded under treatment C. Considering these findings, treatment C was selected as the most effective treatment for extending the shelf life of giant guava, and the shelf life was extended up to 13 days at room temperature.

Table 2 Variation in coating pickup with changes in the sunflower oil percentage and dipping time in the coating solution

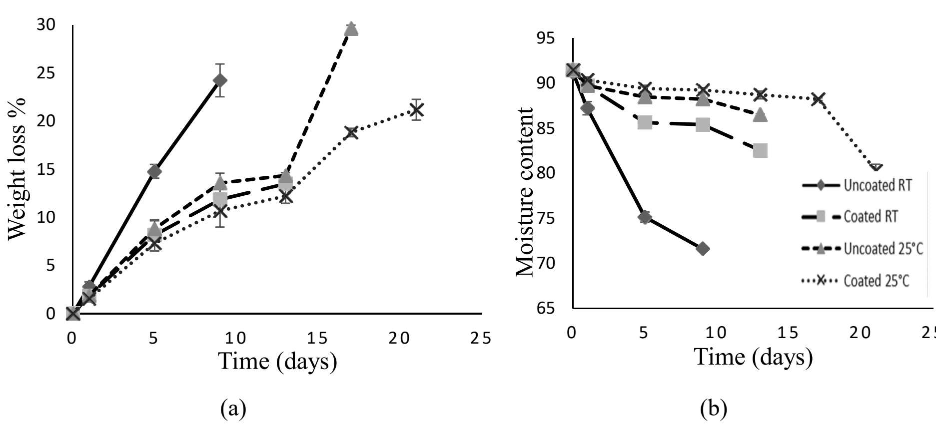
Sunflower oil % (v/v)	*Dipping time (s)*	*Coating pick up (g)*
3.5%	2 s	0.115 ± 0.0302[a]
4.5%	2 s	0.116 ± 0.025[a]
5.5%	2 s	0.124 ± 0.0206[a]
5.5%	2 s	0.124 ± 0.075[a]
5.5%	4 s	0.126 ± 0.043[a]
5.5%	6 s	0.142 ± 0.059[a]

Note: [a]Means within each column with different superscripts are significantly ($p < 0.05$) different.

3.3 Weight loss and moisture content of guava

Figure 2 shows the variation of the weight loss percentage [Figure 2(a)] and moisture content [Figure 2(b)] of guava under storage at room temperature (30 ± 2°C) and a regulated temperature (25 ± 1°C). The results revealed that as the storage period progressed, the weight loss percentage increased. A lower weight loss percentage was observed for guava stored at 25 ± 1°C than that stored at room temperature. Additionally, coated guava showed a lower weight loss percentage compared to uncoated guava. According to Figure 2(a), treatment C significantly reduced the weight loss of coated guava (11.87% at 30 ± 2°C and 10.68% at 25 ± 1°C) compared to that of uncoated guava (24.23% at 30 ± 2°C and 13.59% at 25 ± 1°C) during nine days of storage. Coating provides moisture barrier properties due to the combined effect of beeswax and sunflower oil through the formation of a semi-permeable membrane, which delays shrivelling and wilting. The highest decrease in the moisture content was observed in uncoated guava stored at room temperature, and maximum moisture retention was observed in coated guava stored at the regulated temperature of 25 ± 1°C [Figure 2(b)].

Figure 2 Variation of the weight loss percentage, (a) moisture content (b) guava with storage



The coating reduced fruit softening resulting from the respiration and moisture loss of the fruit. Due to the acceleration of the metabolic rate with increasing temperature, greater weight loss was observed in fruits stored at room temperature than at 25 ± 1°C. Edible coatings act as a semipermeable membrane between the fruit and the surrounding atmosphere, which further reduces the rate of respiration, water loss and oxidation reactions. Soares et al. (2011) reported similar observations, that uncoated guava presented greater weight loss of 20% on the 8th day, while guava coated with 1.5% chitosan showed only 11.8% weight loss during the same storage period. Sothornvit (2013) observed that in comparison to uncoated guava, a beeswax-based edible coating reduced weight loss by 9%. The results of the present study proved that coating delayed weight loss by 50% compared with uncoated guava during storage due to the moisture barrier properties of beeswax and sunflower oil. Furthermore, the coating minimised weight loss by decreasing fruit metabolism and thereby reducing respiratory gas levels at low temperature.

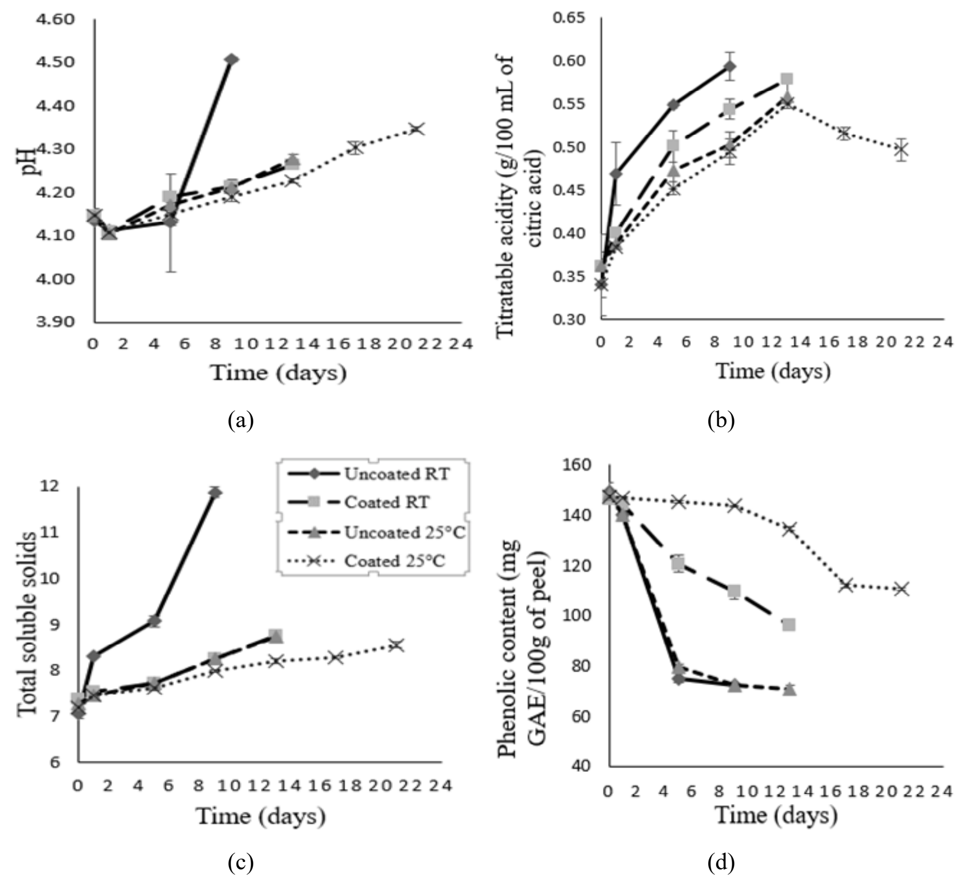
3.4 pH, titratable acidity, TSS content and total phenolic content of guava

Figure 3 shows the variations of the pH [Figure 3(a)], titratable acidity [Figure 3 (b)], TSS contents [Figure 3 (c)] and total phenolic contents [Figure 3 (d)] of guava over time at room temperature and 25 ± 1°C. As shown in Figure 3(a), there was a gradual increase in pH with storage at both storage temperatures. The pH increment of uncoated guava was significantly higher than that of coated guava throughout the storage period [Figure 3(a)]. All fruits stored at room temperature presented greater pH increments than at 25 ± 1°C. However, there was no significant difference ($p \geq 0.05$) in pH values between the coated and uncoated fruits stored at either 25 ± 1°C or room temperature. It has been reported that citric, malic, glycolic, tartaric, and lactic acids contribute to the acidity of guava fruit (Gill, 2016). The decrease in the ascorbic acid content of guava during ripening (Sing and Pal, 2008) and the utilisation of organic acid for the ripening of guava may be the reason for the increase in pH during storage. The results revealed that uncoated guava ripened faster than coated guava due to the rapid production of organic acids during ripening and the utilisation of these acids for metabolism (Zaki El-Sisy, 2013). Sothornvit (2013) reported the similar observation that uncoated guava showed a gradual increase in pH during storage up to the maturity stage.

Figure 3(b) shows the titratable acidity of coated and uncoated guava during storage at 25 ± 1°C and room temperature. The titratable acidity of both coated and uncoated fruits increased to a climacteric peak and then decreased gradually as the storage period was prolonged. However, these differences in coated and uncoated fruits were not statistically significant ($p \geq 0.05$) when stored at either 25 ± 1°C or 30 ± 2°C [Figure 3(b)]. The reason for the increase in the acidity of the fruits is the production of organic acids with ripening, and the acidity decreases after harvesting, as these organic acids are respired or converted to sugars (Raghav et al., 2016).

Figure 3(c) shows the contents of TSS in the coated and uncoated guava during the storage period at two different temperatures (25°C and room temperature). The results indicate that the TSS of guava increased gradually as the storage time progressed. The TSS contents of the uncoated fruits stored at both 25°C and room temperature were higher than those of coated fruits. The TSS increment was significantly ($p < 0.05$) higher in uncoated guava than in coated guava since the TSS of uncoated guava stored at room temperature increased from 7.07 to 11.87 over nine days, while the TSS of coated guava increased from 7.37 to 8.25 over the same period [Figure 3(c)]. The results revealed that regulated temperature storage (25 ± 1°C) further reduced the rate of TSS increase. Throughout the storage period, coated guava stored at 25 ± 1°C showed the minimum TSS increment, while the final TSS value obtained after 21 days of storage was 8.55, which was significantly less than the TSS value of uncoated guava. Hassan et al. (2014) observed similar trends in wax-coated tangerine citrus, as did Shahid and Abbasi (2011) in wax-coated sweet orange. A TSS increment can be observed in climacteric fruits with ripening due to the breakdown of complex carbohydrates into water-soluble sugars, which indicates that the fruits are undergoing ripening. Furthermore, edible coating modifies the internal atmosphere of the fruit by increasing CO_2 levels, thereby suppressing ethylene production and retarding fruit ripening (Abreu et al., 2012). Due to a reduction in temperature, the ripening process is retarded, thus slowing the hydrolysis of starch to soluble sugars.

Figure 3 Variation of the pH, (a) titratable acidity (b) TSS content (c) total phenolic content (d) guava with time at 30 ± 2°C and 25 ± 1°C



The changes in the TPC during storage are shown in Figure 3(d). Coated guava showed a significantly ($p < 0.05$) higher TPC value compared with uncoated guava due to delayed ripening. The total phenolic content of uncoated guava stored at room temperature decreased from 149.59 to 72.57 mg GAE/100 g, while in coated guava, it decreased from 146.07 to 109.50 mg GAE/100 g over nine days. The TPC reduction of 36.57 mg GAE/100 g observed in coated guava was nearly half of the value obtained for uncoated guava, of 77.02 mg GAE/100 g.

Similar to many other fruits and vegetables, Guava is rich in antioxidants that help to reduce the incidence of cancer, heart disease, inflammation and brain dysfunction (Saroja, 2015). Polyphenols and ascorbic acid are the most abundant antioxidants in guava (Chiari-Andréo et al., 2017; Alothman et al., 2009). Tannins are phenolic compounds found in guava that exhibit a sufficiently high molecular weight to form stable complexes with proteins and other polymers, which disappear due to polymerisation during fruit ripening (Bashir and Abu-Goukh, 2003). Thus, it is clear that the coating of guava with a mixture incorporating TSP and beeswax slowed the reduction in TPC compared with that in uncoated guava due to slowing the ripening process.

3.5 The physical appearance of guava

Table 3 presents the changes in the physical appearance of guava over storage time at ambient storage and 25 ± 1°C. Guava fruit usually shows a clear change in skin colour from light green to greenish-yellow during ripening. Injury symptoms of lenticel and skin browning can be observed due to the spoilage of guava. In the present study, under both storage temperatures, coated guava exhibited in a more favourable appearance than uncoated guava (Table 3). Uncoated guavas showed black spots (lenticel) after five days of ambient storage (30 ± 2°C), while coated guava did not show black spots until after 13 days. Coated guava stored at 25 ± 1°C retained an acceptable appearance for 21 days, while black spots started to appear in uncoated guava stored at 25 ± 1°C from day 13 onwards. Similar results were reported by Ruzaina et al. (2013), who observed that the yellow colour of uncoated guava increased from the fifth day onwards.

Furthermore, Saltveit (2004) demonstrated that fruit yellowing is delayed with a delay of ripening due to storage at a lower temperature. Black spots started to appear on the surface of guava due to attack by yeast and mould. A significant reduction of the yeast and mould count was recorded in coated guava due to the incorporation of TSP into the coating mixture. Thus, the present study revealed that by applying a composite coating mixture containing TSP, beeswax and sunflower oil, the spoilage of guava was reduced, and the green colour of guava was maintained for a more extended period.

3.6 Sensory acceptability

Coated guava stored at room temperature (30 ± 2°C) was acceptable up to 13 days, while uncoated guava stored at room temperature was acceptable up to only four days according to the sensory acceptability assessment. Coated guava stored at 25 ± 1°C was acceptable for 21 days, while uncoated guava stored at 25 ± 1°C started spoiling after 13 days. Throughout the storage period of 21 days, the highest mean rank for all the sensory attributes was obtained for coated guava stored at 25 ± 1°C. During storage, brown spots appeared on the surface of both coated and uncoated guava due to spoilage. However, uncoated guava stored at room temperature started to spoil earlier (4th day) than coated guava (13th day).

Table 3 Changes in the physical appearance of guava changes over time (see online version for colours)

Treatment	*Storage period*					
	1 day	*5 day*	*9 day*	*13 day*	*17 day*	*21 day*
Uncoated Guava stored at RT (30±2°)	 Green skin	 Brown spots appeared	 Spoiled	 Spoiled	 Spoiled	 Spoiled
Coated Guava stored at RT	 Shining green skin	 Shining green skin	 Shining green skin	 Green skin less shining	 Spoiled	 Spoiled
Uncoated Guava stored at 25°C	 Green shining skin	 No shining nature	 Green skin no shining	 Brown spots appeared	 Spoiled	 Spoiled
Coated Guava stored at 25°C	 Shining green skin	 Shining green skin	 Shining green skin	 Shining green skin	 Shining green skin	 Brown colour spots appeared

3.7 *Microbial safety*

There was a significant increase in the yeast and mould count of guava with storage. Coated guava showed a lower count of yeast and mould than uncoated guava throughout the storage period. The applied coating consisted of TSP, which possesses antimicrobial properties that reduce yeast and mould counts (Vijay, 2013). The incorporation of antimicrobial agents into edible coatings provides greater inhibitory effects against spoilage and pathogenic microorganisms by maintaining sufficient concentrations of the active compounds on fruit surfaces (Shiekh et al., 2013). Soares et al. (2011) demonstrated that coatings containing 1.0% and 1.5% chitosan presented higher antimicrobial efficiency in the inhibition of filamentous fungi and yeast. It has been reported that beeswax exhibits a synergistic effect as an antibacterial agent with natural products, especially with olive oil (Fratini et al., 2016). The results of this study show that the combined effect of incorporating minute amounts of TSP, beeswax and sunflower oil into a water-based lipid coating reduces the bacterial, yeast and mould counts on the surface of guava while extending the shelf life of fruit with higher sensory acceptability.

4 Conclusions

A natural, low-cost, thin water-based edible biopolymeric coating can be produced with a combination of 0.05% (w/v) TSP, 1% (w/v) beeswax, 0.5% (v/v) emulsifier (Tween 80) and 5.5% (v/v) sunflower oil for enhancing the post-harvest shelf life of giant guava. Dipping the fruit in the coating solution for 6 s maximises the coating's effectiveness. This coating can preserve giant guava for 13 days at room temperature (30 ± 2°C) and 21 days at 25 ± 1°C without damaging the sensory appeal and quality of the fruit.

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