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Articles

Examining The Applicability of Beeswax and Cassava Starch to Extend the Postharvest Life of Mangoes (Mangifera indica)

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Abstract

Mango (Mangifera indica) cultivar 'Buxton spice' is a delicacy as a fresh fruit in Guyana because of its unique quality and flavour. The fruit is highly perishable after harvest causing economic losses along the postharvest marketing chain. Four treatments were applied to determine their effectiveness in extending the postharvest life of 'Buxton Spice': (1) beeswax, (2) beeswax and cassava starch, (3) cassava starch and (4) control, untreated. The treatments were arranged in a randomized complete block design, storing the fruits at ambient and refrigerated conditions. Three replicates each consisting of three fruits for each treatment were analysed at 3, 6, 9, 12 and 15 days after harvest for quality parameters. A panel of untrained persons familiar with quality of mango assessed the fruits for an indication of consumer acceptability. Fruit weight loss increased with its corresponding decrease in firmness with the beeswaxed fruits having the least weight loss and maintaining firmness for up to day 15. The beeswaxed treated fruits developed an 'off flavour' after nine days of storage while those treated with beeswax and starch composite had the best quality and was therefore the most acceptable among the treatments in extending postharvest life. This treatment (beeswax and starch) can therefore be applied to mango to reduce production and economic losses.

Keywords: *Postharvest Storage, Edible Coatings, Beeswax, Cassava Starch, Physicochemical Changes*

Introduction

Mango (*Mangifera indica L.)* is a stone fruit; the flesh is peach like and juicy; the skin is leathery, smooth, fairly thick, yellow-orange and reddish-pink when fully ripe. Some varieties have a turpentine odour and flavour with a pleasant fragrant and exceptional taste (Morton, 1987). It is a climacteric fruit, characterized by a series of biochemical changes initiated by an autocatalytic production of ethylene and the consequent increase in respiration as it ripens. During ripening, the significant physico-chemical attributes influencing quality are firmness, flesh colour, total soluble solids content, titratable acidity, and aroma volatiles (Padda et al., 2011). Mango is an excellent source of dietary fibre and bioactive compounds such as provitamin A, carotenoids, vitamin C and phenolics, which are essential to human nutrition and health (Samad, 1975). In Guyana, there are several cultivars of mangoes, however, the most flavourful and preferred cultivar is the 'Buxton Spice'. Hence, 'Buxton Spice' is the leading cultivar produced. It is a medium-sized fruit with a golden-yellow skin colour when ripe and has relatively low fibre content

(Ministry of Agriculture, 2007). In order to accelerate production and export, there is need to determine a suitable postharvest treatment.

Edible coatings are used to extend postharvest life. They are made of a variety of polysaccharides and are derivatives of marine, agricultural plants and animals. Coatings reduce aroma loss, retain moisture and delay colour change throughout storage, retard shrinkage and prevent spoilage. These coatings are used to retard transfer of gas, vapour and volatiles. The modified atmosphere in the fruit is due to decrease respiration which delays senescence. The properties of the coatings are affected by characteristics such as their solution composition, viscosity and thickness. The plant variety, fruit or vegetable maturity, previous fruit treatment and fruit surface coating also influence the effectiveness of the applied coating (Kolattukudy, 1984; Olivas and Barbosa-Cánovas, 2009; Dhall *et al*., 2013). Beeswax, wood resin, cassava starch and carnauba wax from palm trees are among the organic waxes used to extend postharvest life (Fallik *et al.*, 2005). Phan et al., (2005) observed that cassava starch was the best of the starch-based films applied to preserve food quality. When beeswax is added to starch films it increases the mechanical, physical and thermal properties of treated fruits (Han *et. al*., 2006). Formulations of beeswax and starch extended the shelf life of peach and pea (Oliveira and Cereda, 2003; Han et al., 2006).

The climacteric properties of mango mean that when harvested, they ripen and soften quickly. Thus, if it is required that they remain a long time for shipment or storage for local sales an effective postharvest method should be applied. Baldwin *et al.,* (1999) found that two coatings, one polysaccharide based and the other with carnauba as the main ingredient applied to mango (*Mangifera indica*) in modified atmospheres, reduced decay and improved appearance of the fruit. Carnauba wax was better at reducing water loss compared to the polysaccharide coating treatments. Among various coatings tested on mango, beeswax was the best at preventing water loss while the starch-base coating fruit had the best quality (Bibi and Baloch, 2014). Junior *et al.,* (2007) also determined that 3% starch reduced water loss, extended shelf life and improved the visual appearance of the mango. However, as indicated by Dhall (2013) starch alone does not have the mechanical property to form an adequate coating. Previous studies by Abbasi *et al.,* (2011) demonstrated the extended shelf life of coated mangoes in refrigerated conditions.

The objective of this study was to investigate the influence of beeswax, cassava starch and a combination of beeswax and cassava starch in extending the shelf life of mango while maintaining quality in ambient and refrigerated conditions.

Materials and methods

Mangoes, cultivar 'Buxton Spice', were purchased at a mature green stage from a farmer and taken to the laboratory of the Faculty of Agriculture and Forestry, University of Guyana where they were examined individually for firmness and defects. The firmer fruits, uniform in size and with no defects were selected for the experiment. The fruits were immersed and washed thoroughly in running water, they were removed and air-dried. An initial physico-chemical analysis was conducted on a sample of fruits.

Four treatments were prepared:

(i) melted purified beeswax

(ii) starch emulsion prepared by suspending 80 grams of cassava starch made up to a volume of 500 ml with water and placed unto hot plate with constant stirring until gelling

(iii) The starch and beeswax emulsion obtained by mixing 80 grams of cassava starch, 80 grams of beeswax, 40 grams of glycerol, 5 grams of potassium hydroxide (KOH) and 10ml of ethyl ether as antifoaming agent with 800ml of water in a suitable container and heating for 30 minutes adapted from Oliveira and Cereda (2003) and

(iv) Untreated, that is, no coating.

Of the 360 fruits selected, ninety fruits were used for each treatment. For the three coatings, fruits were dipped for about five seconds to give one layer. Following this, 45 fruits from each treatment, totalling 180 fruits, were stored in ambient temperature and the other 180 in refrigerated conditions. Three replicates each of three fruits from each treatment were analysed every 3 days for 15 days for those stored in refrigerated conditions and ambient conditions. Analyses were conducted on the physico-chemical attributes that influence quality and consumer acceptability. Fruit weight loss was expressed as a percentage of the initial weight of each fruit. A handheld SSEYL GY – Fruit penetrometer was used to determine the firmness of the fruit by puncturing opposite sides of each fruit where two circular discs of the peel were removed. Firmness was recorded as pound per square inch (psi) of pressure.

The three fruits of each replicate were macerated to extract the juice and pH was determined with a Hanna HI 8424 pH/ temperature meter. Analysis of juice for total titratable acidity as malic acid was conducted by titrating with 0.1 N NaOH to pH of 8.2; soluble solids concentration recorded as °Brix was measured with a Lab Digital Refractometer (digital refractometer 30035 Sper Scientific). Change in peel colour was observed over the various periods of analysis for both refrigerated and ambient storage conditions using a numerical scale; 4- yellowish green 3- greenish yellow, 2- light green and 1- green. For the organoleptic test, a panel of eight untrained members familiar with the taste and flavour of mango provided an indication of consumer acceptability using a 5 point hedonic scale this included, 5- Delicious, 4- Good, 3- Fair, 2- Bad, and 1 very bad. The data were analysed by Analysis of Variance (ANOVA) and least significant difference (LSD) test using Statistics 10 software. The means were separated using the least significant difference (LSD) at 95% confidence limit.

Results and Discussion

Weight Loss:

The percentage weight loss was a function of both storage period and the type of coating used (Figure 1). Regardless of the storage temperature or type of coating, the percentage weight loss increased with time of storage. The application of beeswax produced significantly less weight loss than the untreated fruits throughout the storage period. There were significant differences among the coatings for water loss for both storage conditions ($p = 0.000$). In ambient condition, from day 6 to day 15, the untreated fruits had significantly higher weight loss than the treated fruits while among the treated fruits from day 9 to day 15, those treated with beeswax only had the lowest weight loss which was significantly different from the other treated fruits. For mangoes stored in the refrigerator, those dipped in beeswax had significantly lower weight loss for all days analysed except for day 3.

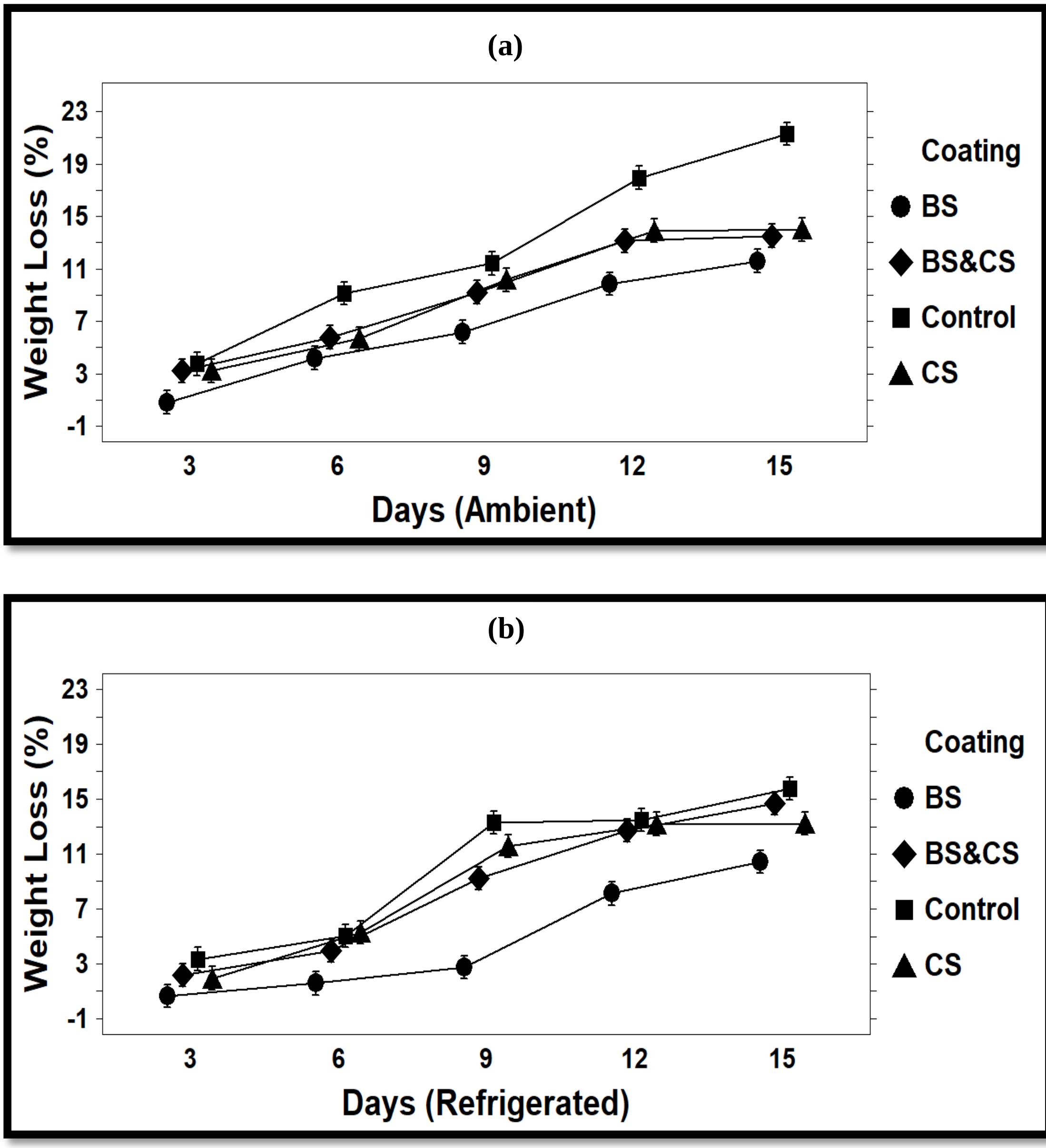
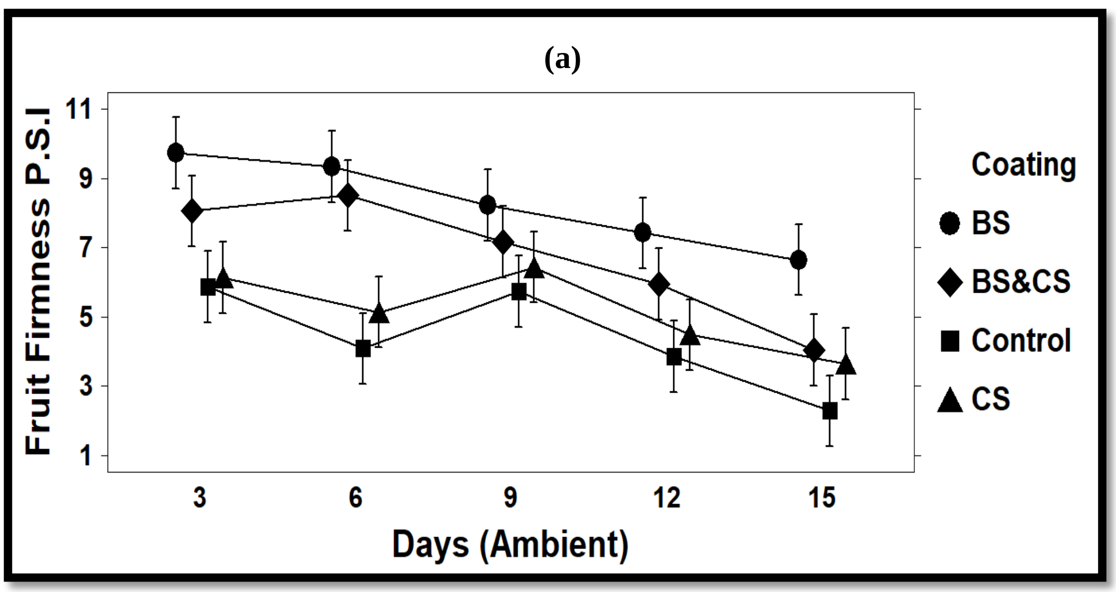


Figure 1: The weight loss (%) of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

After 15 days of storage at temperatures (10-15°C) weight loss ranged from 0.1% to 16.7% of the initial fruit weight and at room temperature weight loss ranged from 0.5% to 23%. Patil et al., (2016) also observed lower weight loss in mango at 20^{o}C than at higher temperature of 25^{o}C and 30^{o}C. Generally in fruits, weight loss is due to respiration and transpiration of water through the peel tissues of the fruit. The untreated fruits had the greatest percentage of weight loss while beeswax coated fruits had the least for both ambient and refrigerated conditions. Related studies by Baldwin *et al.,* (1999) also reported reduced weight loss in the coated fruit compared to uncoated controls, while Bibi and Baloch (2014) determined that beeswax-treated fruits had the lowest weight loss among various coatings tested including those treated with starch. Jatoi et al., (2018) also observed that temperature influences weight loss since Goji berries stored at 0°C and −2 °C had much lower weight loss than those stored at 20°C.

Firmness:

Fruit firmness decreased over the storage period (Figure 2). Under ambient conditions across the storage period, beeswax coated fruits had the highest firmness followed by fruits coated with the combination of beeswax and cassava starch while untreated fruits retained the least firmness. Differences among these treatments were significant (p = 0.0133). The observation was the same for refrigerated conditions and overall beeswax coated fruits had the highest mean firmness of 8.3 psi which was significantly different from the fruits coated in the combination of beeswax and cassava starch at 6.7 psi; cassava starch 6.3 psi and untreated 5.1 psi (p = 0.0398). Changes to fruit firmness are partly due to water loss.The ripening of mango fruits is also characterized by a loss of firmness due to cell wall digestion by cellulase, pectinesterase, polygalacturonase, glycanases, glycosidases, endomannanase and α-mannosidase and other enzyme and nonenzymatic processes (Selvaraj and Kumar 1989, Mitcham and McDonald 1992; Narain *et al.,* 1998, Yashoda *et al*., 2007). The use of X-ray and confocal laser scanning microscopy demonstrated that these enzymatic activities result in the disintegration of the self-assembled network of polymers such as pectins and hemicelluloses into individual molecules with consequent loss of firmness (Cárdenas-Pérez et al., 2018). The effectiveness of the coatings is in slowing down the changes associated with loss of firmness.



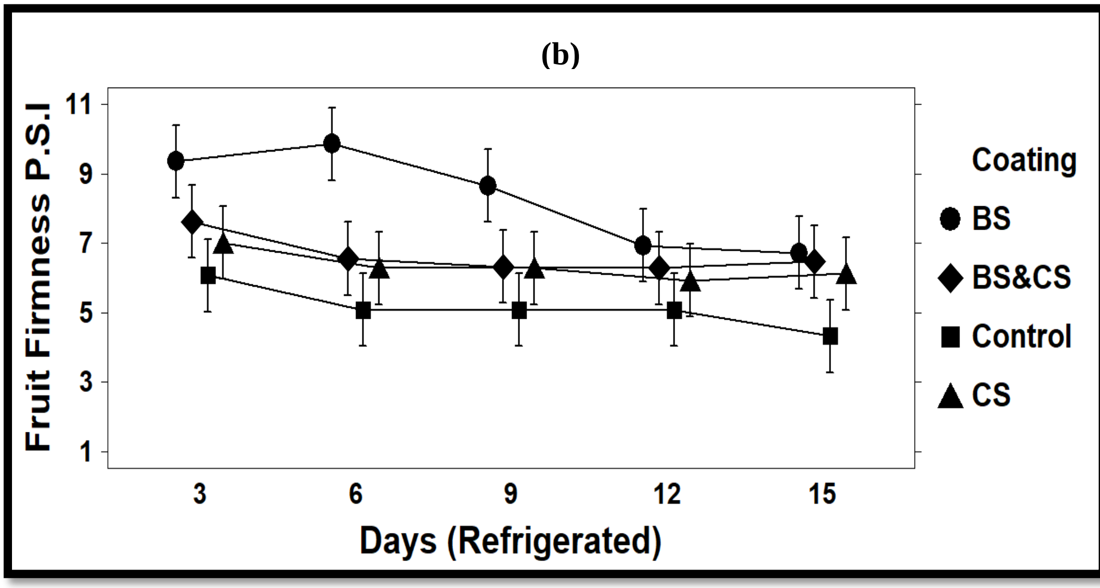
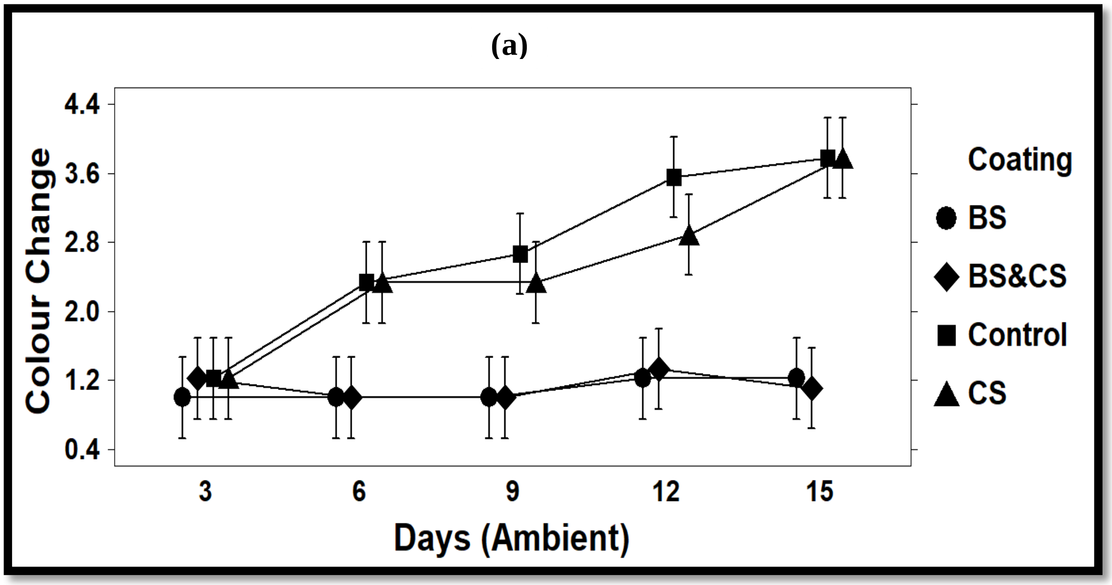


Figure 2: The Firmness of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

Colour change:

'Buxton Spice' mangoes showed its characteristic development from green to yellow colour from day 3 to day 15 (Figure 3). The change in peel colour is as a result of the degradation of the chlorophyll structure and an increase in the carotenoid pigments during storage upon ripening of fruits (Mitra and Baldwin, 1997). The enzyme chlorophyllase, pH changes and oxidative systems are involved in chlorophyll breakdown (Wills et al., 1998). Overall there were significant differences among the coatings and for the days of analysis. Beeswax only and Beeswax combined with starch slowed the development of colour from green to yellow. This was more pronounced in ambient condition where from day 6 to day 15, where the two types of treatments had slight changes in colour and were significantly different from the control and those treated with starch only (Figure 3a). However, untreated fruits stored in the refrigerator showed increase in colour from day 9 (Figure 3b). Overall ambient-temperature-stored fruits changed colour at a faster rate than the refrigerated-stored fruits. Similar studies by Patil et al., (2016) with mango var Alphonso showed that there was slower colour development at the lower temperature of 20°C than at higher temperatures, 25°C and 30°C. Among the treatments, beeswax coated fruits had a slower rate of colour development from green to yellow. Feygenerg et al., (2004) also observed that in 'Tommy Atkins' mango, beeswax delayed colour change.



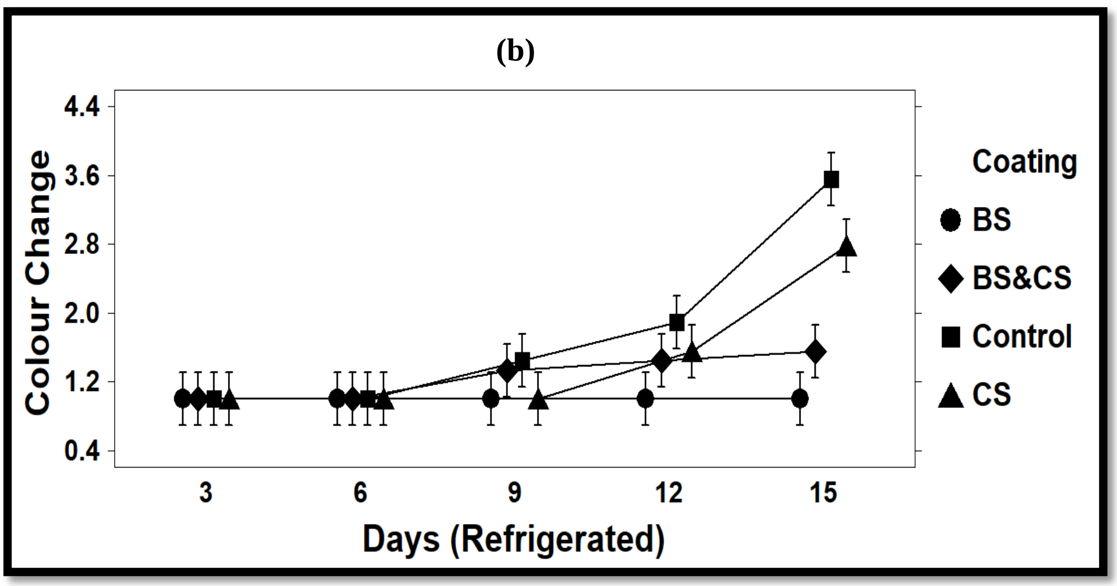


Figure 3: Colour Change of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

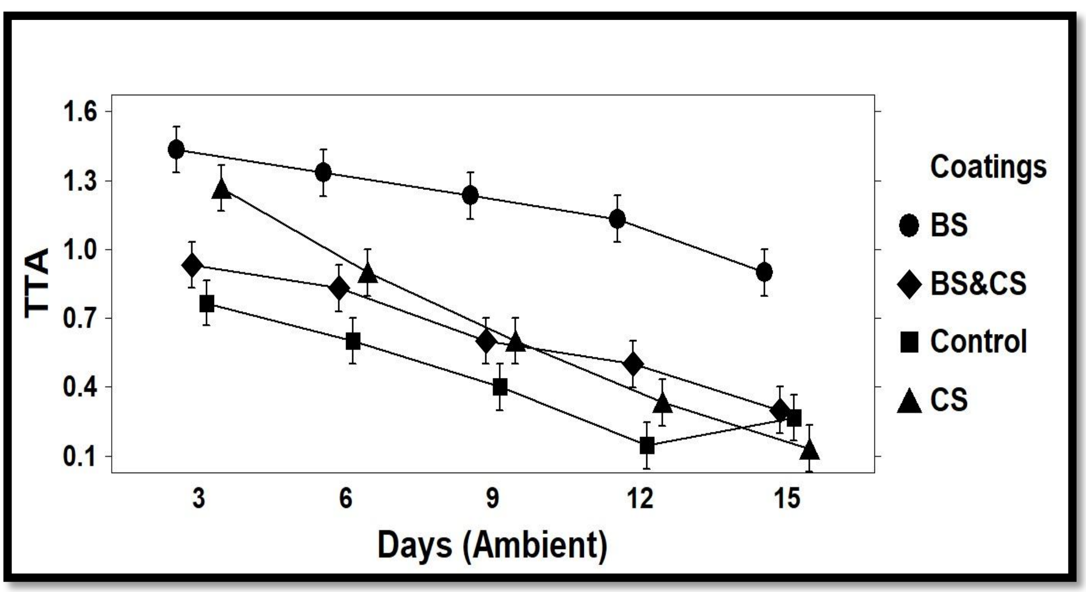
Total titratable acidity:

Total titratable acidity measured as malic acid decreased during storage at both ambient and refrigerated conditions, due to the hydrolysis of starch leading to an increase in total sugars and a reduction in acidity (El-Ghaouth, 1991). At both ambient and refrigerated conditions, the mean of the beeswax coated fruits were significantly higher than the other treatments (Table 1).

Table 1. Average values for total titratable acidity, total soluble solids and pH of mangoes treated with beeswax, cassava starch, combination of beeswax and cassava starch and control stored in ambient and refrigerated conditions for 15 days.

Variable	Treatment	Ambient	Refrigerated
Total titratable acidity (mEq NaOH/100 g)	Beeswax	1.21a	1.15a
	Cassava Starch	.66b	0.55b
	Beeswax & CS	.65b	0.61b
	Control	.44c	0.58b
pH	Control	4.65a	3.80a
	Cassava Starch	4.39b	3.79a
	Beeswax & CS	4.16c	3.45b
	Beeswax	3.82d	3.27c
Soluble solid content (Brix)	Control	10.86a	10.19a
	Beeswax & CS	10.60a	9.83a
	Cassava Starch	8.47b	8.01b
	Beeswax	6.94b	5.75c

Generally, for refrigerated fruits TTA ranged from 0.1 to 1.6 while in ambient stored fruits values ranged from 0.1 to 1.5 (Figure 4). The untreated fruits had the lowest mean of malic acid. This result is similar to studies by Kittur *et al.,* (2001) where the coated mango had a higher acid content than the uncoated mango.



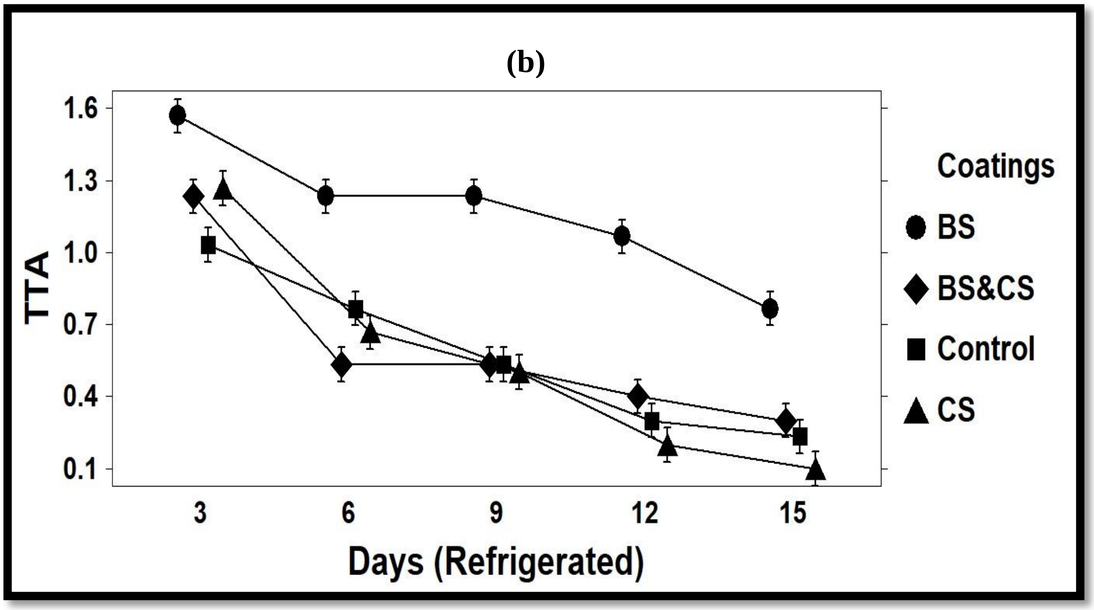


Figure 4: Total Titratable Acidity of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

pH:

In addition to titratable acidity, pH is used to measure acid levels in fruits and vegetables. In mango, pH is a good predictor of biting (The stinging sensation felt on the tongue after drinking carbonated drinks such as soda), astringency and sourness (Malundo et al., 2001). With the decreasing total titratable acidity, pH increased over the storage period. The loss in acidity may be as a result of a large decrease in citric acid and a small reduction in malic acid (Medlicott and Thompson, 1985). Untreated fruits had the highest pH in both storage conditions. Refrigerated stored fruits pH values ranged from 2.7 to 4.9 while fruits stored in ambient temperature ranged from 2.7 to 5.2 (Figure 5). There were significant differences among the coatings for each day of analysis (p=0.000).

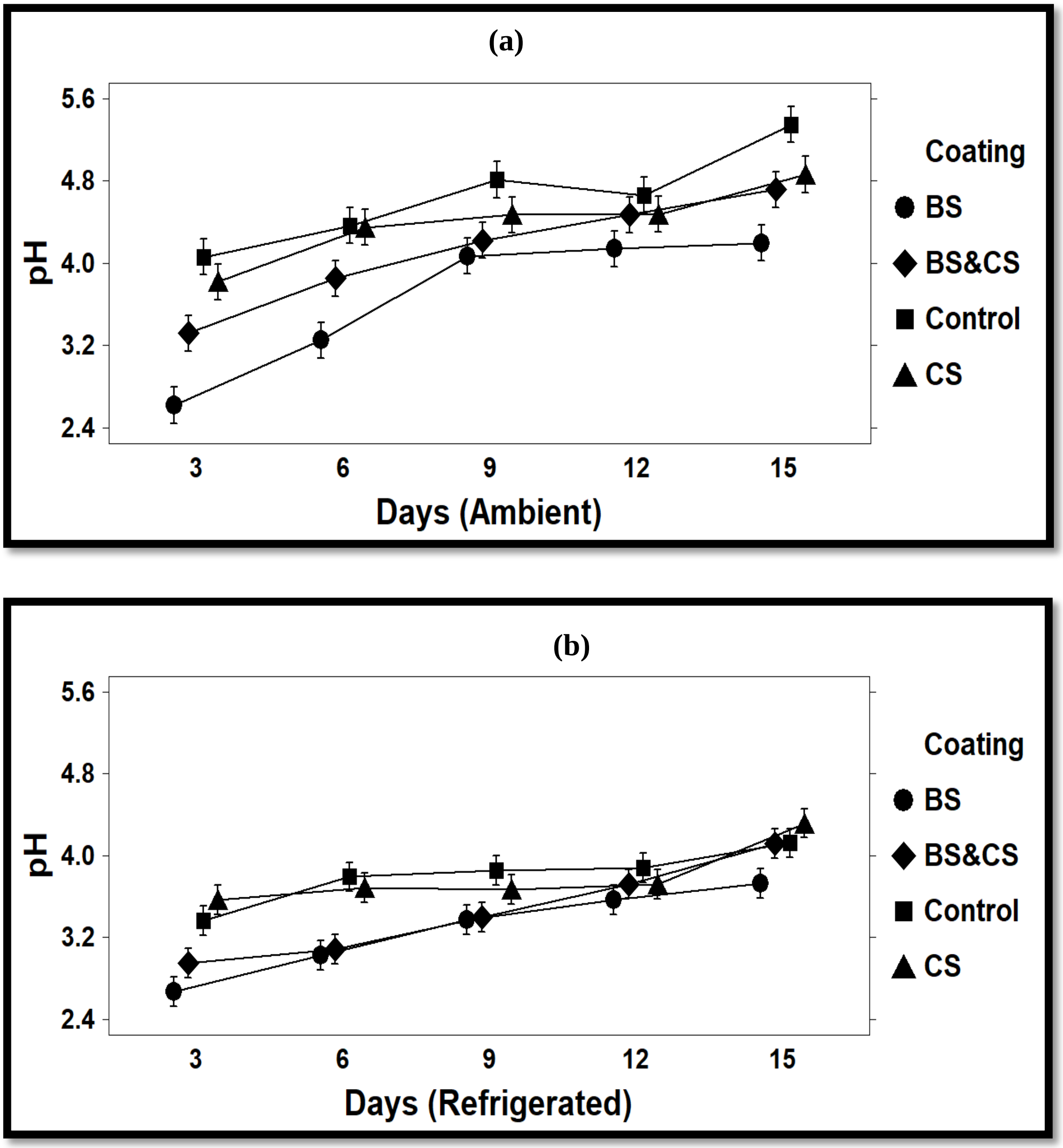


Figure 5: pH of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

Total Soluble Solids (TSS):

The total Soluble Solids content of fruits increased over the storage period for both tested conditions up to day 12 and declined by day 15 (Figure 6). Total Soluble Solids content was slightly higher in ambient-stored fruits than those stored in the refrigerator (Table 1). Untreated fruits had the highest content of sugar 10.9^{o} Brix in ambient condition and 10.2^{o} Brix refrigerated condition; additionally, beeswax coated fruits had the least total soluble solids content of 7^{o} Brix and 5.8^{o} Brix in ambient and refrigerated conditions respectively. Total soluble solids content in fruits increases owing to the transformation of starch into soluble sugars as the carbohydrates in the fruit are broken down during ripening to form simpler sugars. Total sugars of the fruit are considered one of the basic criteria to evaluate fruit ripening. In mango, the major sugars are sucrose, glucose and fructose (Medlicott and Thompson, 1985).

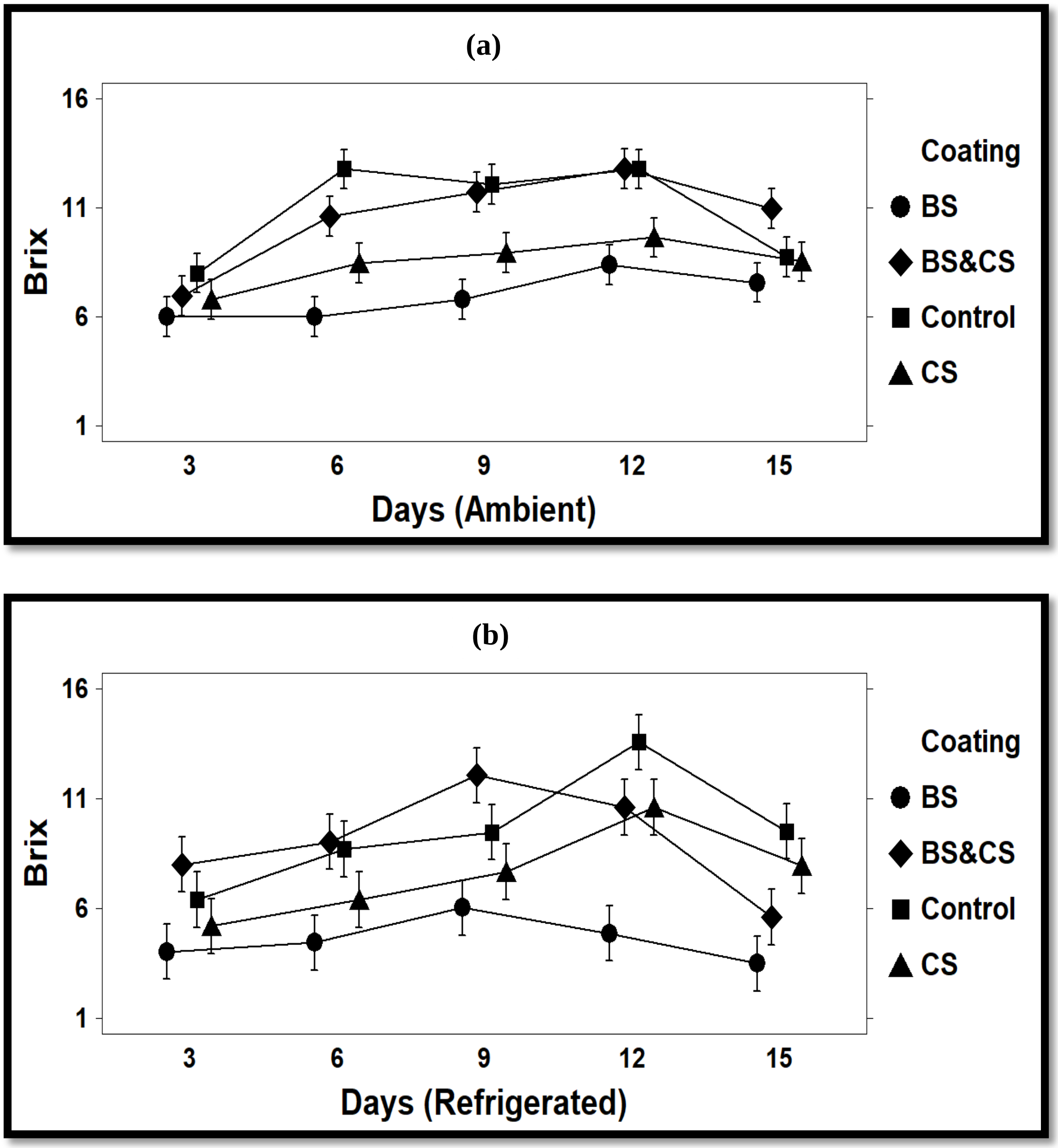


Figure 6: The Brix of mangoes coated with Beeswax (BS), Cassava starch (CS), Combination of Beeswax and Cassava starch (BS&CS) and Control over the storage period of 15 days at both ambient conditions (a) and refrigerated conditions (b).

Initial test conducted before storage indicated that the TSS was 4.8^{o} Brix and during storage as ripening progressed total sugars increased in all treatments. The higher concentration of sugars in untreated fruits was due to the faster rate of conversion of starch into sugars, along with moisture loss and decrease in acidity due to the physiological changes during storage. The observed increase in total soluble solids and decrease in acidity as a result of metabolic reactions in the fruit were similarly reported by Gowda and Huddar (2001), and Padda *et al.* (2011) where the physico-chemical changes in mango as it ripened were examined.

Organoleptic Test

Overall fruits coated with beeswax and cassava starch had the highest rating for both conditions of storage. Based on sweetness alone untreated fruits was most preferred up to day 9 of storage owing to optimum ripeness. The mean separation for each day of analysis showed they were significant differences for each coating with regard to the pulp flavour quality. As pointed out by Perez-Gallardo *et al.,* (2015), the beeswax and starch combination allows for gas exchange (O_2 and CO_2) and reduced accumulation of volatile compounds associated with fermentatative metabolism. Beeswax-coated fruits developed an off-flavour after nine (9) days of storage for ambient stored fruits. As noted by Baldwin *et al.,* (1998) polysaccharide-based coatings can potentially cause mango to become sour as a result of accumulation of ethanol and CO_2 in the mesocarp.

Conclusion

The beeswax, cassava starch and the combination of beeswax and cassava starch coated in ambient and refrigerated temperatures slowed down the physico-chemical changes that occurred during ripening. Although, the fruits coated with beeswax and the combination of beeswax and starch had relatively less weight loss, slowed down the ripening and had an acceptable appearance during the storage period; those coated with beeswax only had an undesirable taste after 9 days of storage in ambient conditions. Fruits coated with the combination of beeswax and cassava starch were acceptable for all the quality parameters up to 15 days of storage and is therefore the best of the coatings tested for both ambient and refrigerated storage conditions.

The results of this study can be applied in the fruit industry in Guyana. Beeswax and Cassava Starch are readily available in Guyana and therefore exporters and all stakeholders involve in the production and marketing chain should be exposed to training on the application of these coatings to extend postharvest life. This would result in more export of the fruit internationally earning much-valued foreign exchange for the country. Concomitantly mango cultivation should increase.

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