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Influence of Wax Coating on Extending the Shelf Life of Mango (*Mangifera indica* L.) cv. Karuthakolomban

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Abstract: Extending the shelf life of mango is important for their successful marketing. In this context, different edible coatings have been used for prolonging the storage life and preserving the quality of fresh fruits. Effect of Gum Arabic, Chitosan and IPHT bio wax as edible coatings on pH, Titratable Acidity (TA), Total soluble solids (TSS), firmness, peel colour of L*(black to white), a*(redness to greenness), and b* (yellowness to blueness)values and shelf life of mango fruits were investigated. Chitosan 0.8% (CH), Gum Arabic 8% (GA) and IPHT bio wax 1:25 (IPHT) were selected as the optimum concentrations from pre-treatments. Mango fruits were treated with the selected concentration of each wax and they were evaluated for their ability to extend the storage life. Treated mango fruits were stored at 13±1°C and 90% relative humidity during the storage period. Significant differences were observed ($P<0.05$) for tested parameters in fruits treated with CH, GA and IPHT bio wax when compared to the control. CH, GA, IP HT and control samples showed storage life of 27, 23, 24 and 18 days, respectively. There wereno significant differences ($P>0.05$) observed between the treatments of GA and IP HT for pH, TA, TSS, firmness and peel colour values of L*, a*, and b*. These results suggested that application of Chitosan 0.8%, Gum Arabic 8% and IP HT bio wax 1:25 coating as bio preservative might be an effective technique for extending the shelf life and maintaining the quality of mango cv. Karthakolomban fruits during cold storage where Chitosan 0.8% is the best treatment.

Keywords: Chitosan, Gum Arabic, IP HT bio wax, Mango, Post-harvest

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Introduction

Mango (*Mangifera indica* L.) is a major fruit crop of the tropical and sub-tropical regions of the world, especially in Asia. Delicious taste, juiciness, sweetness, attractive fragrance, colour and unique flavour with high nutritional value have made it equally popular across the globe. Its popularity and importance can easily be realized by the fact that it is often referred to as "King of fruits" in the tropical world.

Sri Lanka produces several varieties of mango namely Karthakolomban, Willard Vellaicolomban, Chembatan, Malwana, Betti Amba, Pol amba and TEJC. These mango varieties have higher demand and have commercial importance in food processing and fresh food industries. Karthakolomban is one of the superior varieties of mango popular among growers as well as consumers in Sri Lanka due to its unique flavour and high nutritional value (Kothalawala and Jayasinghe, 2017).

The rapid ripening process is responsible for the short shelf life of mango fruit and it represents a serious constraint for efficient handling and transportation. Mango is a climacteric fruit and the ripening is initiated by ethylene production with a peak of the respiration. With the commencement of the ripening process, cell wall degrading may cause the fruit softening (Gunasekera *et al.,* 2018). Therefore, techniques for storage of mango fruits have to be standardized and employed to enhance the storage life (Mitra and Baldwin, 1997).

Natural products are taking place as an alternative approach to overcome the application of hazardous chemical agents for delaying ripening and reducing post-harvest deterioration of fruits. Edible coatings act as a barrier, decrease gas exchange between fruit and the surrounding atmosphere, resulted in the modified internal atmosphere (high CO_2 and low O_2), as well as decreased water loss (Baldwin *et al.,* 1991). Edible coatings are used as a post-harvest management tool to maintain fruit quality and minimize the size of non-biodegradable packaging materials to extend the storage life of papaya and mango grown in Sri Lanka (Hewajulige *et al., 2013*).In addition, post-harvest cooling enhances marketing flexibility by making it possible to market at more optimum times. The ability to cool and store commodities minimizes the need to market immediately after harvest.

Lipid based edible coating (wax) which was developed by the Institute of Post-Harvest Management (IPHT bio wax) has shown that the shelf life of fresh fruits can be extended without quality deterioration. It can be easily applied to the fruits by dipping in formulated coating solutions with distilled water.

IPHT Bio wax is a lipid based edible coating for fruits which include guar gum as the main ingredient. Edible coating and films have received considerable attention in recent years because of their advantages over synthetic films that they can be consumed with the coating itself. Consumer interest in health, nutrition and food safety combined with environmental concern has renewed effort in edible coating formulations. The edible film defined by two principles: first implies safe to eat or generally recognized as safe (GRASS) by the FDA and second, it must be composed of a film forming material. Therefore, adoption of environment friendly and ecologically safe substances particularly of biological origin can provide a fairly good alternative to the synthetic chemical measures.

Gum Arabic is a polysaccharide natural secretion from Acacia species and used in industries for film forming, emulsification and encapsulation purposes (Motlagh *et al.,* 2006). Gum Arabic coatings effectively maintained total antioxidant and phenolic contents in tomato fruit (Zahid *et al.,* 2013) and papaya (Addai *et al.,* 2013). Gum Arabic treatment reduced browning, loss of ascorbic acid and total phenolic contents of tomato slices (Eltoum and Babiker, 2014). Chitosan has antimicrobial and antifungal activities. It is a linear polysaccharide (a combination of glucose) originating from chitin which comes from the shells of crustaceans including shrimp. Chitosan is a non-toxic, biodegradable, biofunctional and biocompatible compound. Chitosan is a natural biopolymer containing (1, 4)-linked 2-amino-deoxy-β-d-glucan, derived by deacetylation of chitin. It has a wide range of uses in fruit and vegetable, because of its film forming, biochemical properties and antimicrobial activity.

Therefore, the objective of this work was to identify the effect of applying IPHT bio wax, chitosan and Gum Arabic as pre-storage treatments on delaying ripening, enhancing the shelf life and retaining the quality of mango fruits during cold storage.

Materials and Methods

Plant Materials

Mango (*Mangifera indica* L. cv. Karthakolomban) fruits were obtained from Eppawala fruit processing zone which was selectively harvested based on the proper maturity stage of mango. Fruits were transported with minimal delay after harvest and brought to the laboratory at National Institute of Post-Harvest Management. Fruits of uniform size and maturity, free from pests, diseases, injuries, bruises and blemishes were selected for the experiment. Fruits were washed with 5% (w/v) sodium bicarbonate solution for two minutes and air dried at ambient temperature conditions.

Preparation of Dipping Solutions

Gum Arabic solutions were prepared based on the required concentrations by dissolving necessary amounts of gum

Arabic powder in 100 mL distilled water. The solution was heated at 40°C for 60 min, using a hot plate magnetic stirrer (Model SP 18420-26 Barnstead thermolyne 2555 Kerper Boulevard Dubuque, USA). Glycerol 1.0% was also added as a plasticizer to the coating solutions. The pH of the solution was adjusted to 5.6 with 1 mol L−1 sodium hydroxide (Na OH) using a pH meter (GLP 21, Crison, Barcelona). Chitosan coating solution 1% (w/v) was prepared by dissolving 1 g of chitosan in100 mL distilled water containing 1% (v/v) glacial acetic acid. The solution was agitated constantly using a magnetic stirrer for 3 h. The suspension was filtered through a cheesecloth to eliminate the insoluble material. The pH of the solution was adjusted to 5.6 with 1 mol L−1 NaOH, and 0.2 mL of Tween-20 also added to improve wettability. IPHT bio wax was prepared by diluting the IPHT bio wax with distilled water.

In order to identify the optimum concentration of IPHT bio wax, chitosan and Gum Arabic, a series of wax application was done as IPHT bio wax (1:1, 1:2, 1:25, 1:3), Gum Arabic (5%, 6%, 7%, 8%, 9%, 10%) and Chitosan (0.5%, 0.6%, 0.7%, 0.8%, 0.9%). Based on visual observations and sensorial attributes (appearance, aroma, taste, texture) the optimum concentration was selected. The shelf life of mango for each wax was determined by observing the colour development stage as fifty percent (50%) yellowing of the peel which was identified as the marketable stage of mango considering the visual quality and other chemical parameters(total soluble solids content, Titratable acidity and pH)at the ripening stage.

For evaluating the performance of the selected concentration of each bio wax, the mango fruits were randomly divided into four lots of 180 fruits each. Then the dipping treatments were applied to each lot. The first lot was dipped in distilled water as a control. The other three lots were dipped in the corresponding solutions for two minutes. After dipping, fruits were air-dried in ambient condition and they were packed in plastic crates (40 × 30 × 12 cm).The fruits were stored at 13 ± 1°C and 90% relative humidity.

Determination of Weight Loss

Five fruits in each treatment were separately marked before storage and weighed at the start of the experiment. The same fruits were consistently weighed at each sampling interval during the whole storage period. The result was expressed on a percentage basis. The weight of each fruit was measured by using a top-loading electronic balance (Model: SHIMADZU, BL– 2200H).The following equation was used for calculating the percentage of weight loss (P.W.L).

$$\text{P.W.L} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}}$$

Measurement of Fruit Firmness

Fruit firmness was measured using Instron Universal Testing Machine (Model 5543 P5995, USA) connected with computer. Reading was recorded from three points as the proximal, middle and distal portion region of the whole fruit with skin removed, and the results were expressed in terms of force recorded in Newton (N).

Determination of Total Soluble Solidscontent

The total soluble solids content was measu red using a temperature compensated digital refractometer (ATAGO, Model PAL-1) and expressed as a percentage (°Brix). Before taking a reading, it was standardized with distilled water and adjusted to reading 0°Brix.

Measurement of Peel Colour, Titratable Acidity (TA) and pH

Peel colour was measured using Hunter lab colour difference meter (CR 400, Konica Minolta) and the values of L*, a*, and b* were recorded (McGuire, 1992) where L* indicates the lightness and extends from 0 (black) to 100 (white) while a* indicates redness (+) to greenness (-) and b* indicates yellowness (+) to blueness (-) respectively. The measurements at the stem end, mid-region and floral end of each face of the peel were measured and a mean value was obtained. TA was determined as per AOAC (2005) and expressed as grams of citric acid equivalents per 100 ml of juice. Juice pH was measured by a pH meter (230A+, Thermoorion).

Statistical Analysis

The experiment was conducted as a complete randomized design (CRD). The data were subjected to analysis of variance (ANOVA) and means were compared using Duncan multiple range and LSD tests with SPSS statistical software 20.0.

Results and Discussion

Chitosan 0.8%, Gum Arabic 8% and IPHT bio wax 1:25 were selected based on sensorial attributes and visual observations of the peel (Plate 1). Weight loss is used as a quality index in the post harvest life of fruits. The results showed that weight loss gradually increased in all samples during storage (Figure 1).

Weight loss of treated mango fruits was significantly lower than untreated fruits during the entire storage period. In control treatment, there were no data available on the twentieth day of storage as control fruits reached fifty percent ripening stage in the eighteenth day. The highest weight loss was observed in the control fruits at the end of the storage period. These results are in agreement with the findings of previous studies, the same trend has been recorded for coated and uncoated mango (Sharaawi *et al*., 2000).

There was no significant difference (P>0.05) in weight loss percentage between wax treatments. Weight loss reduction in mango fruit treated with Gum Arabic, chitosan and IPHT wax coating could be due to the effects of the wax layer which created a modified atmosphere, and restricted gas exchange and moisture (Kittur *et al*., 2001). Loss of weight in fruits occurs due to transpiration process, depends on the gradient of water vapour pressure between the surrounding atmosphere and the fruit tissue.

Edible coatings act as a barrier on the fruit surface, thereby reducing water transfer, sealing small wounds and thus delaying weight loss.

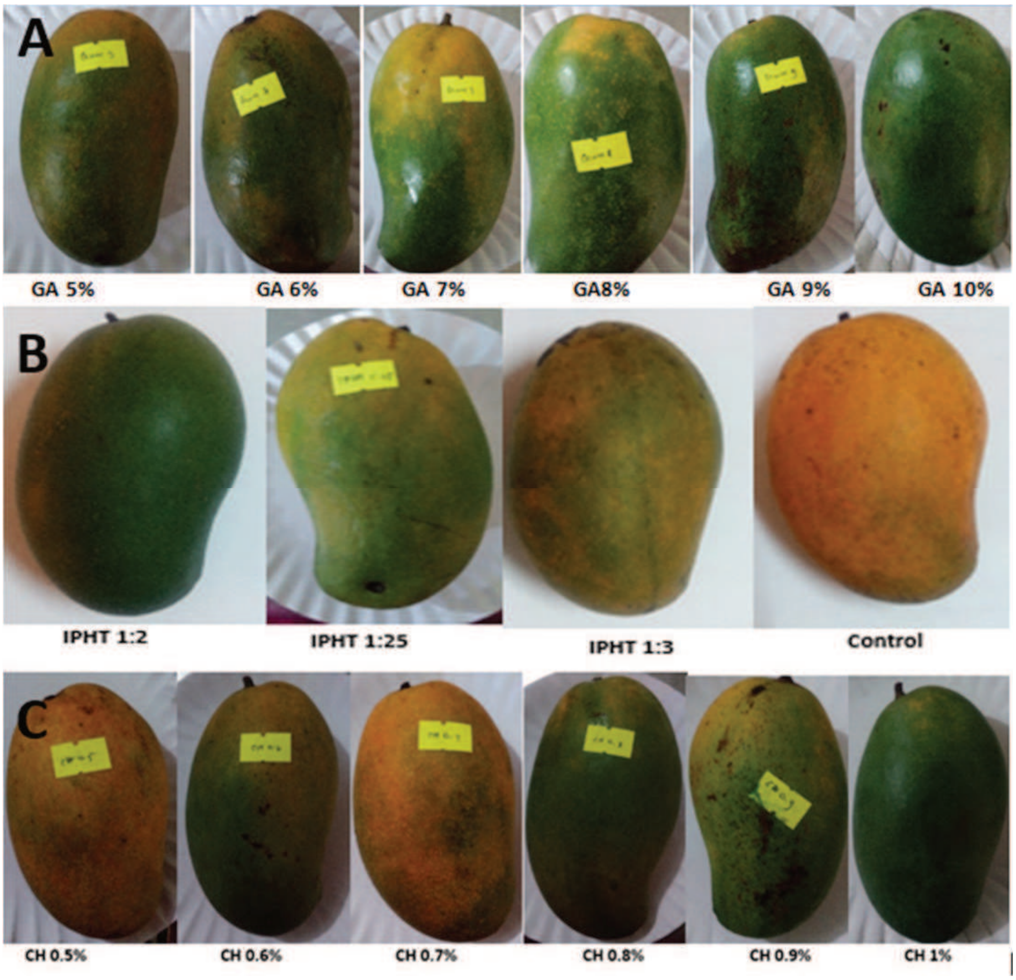

Plate 1: A- wax treatment of Gum Arabic, B- wax treatment of IPHT bio wax, C- wax treatment of Chitosan

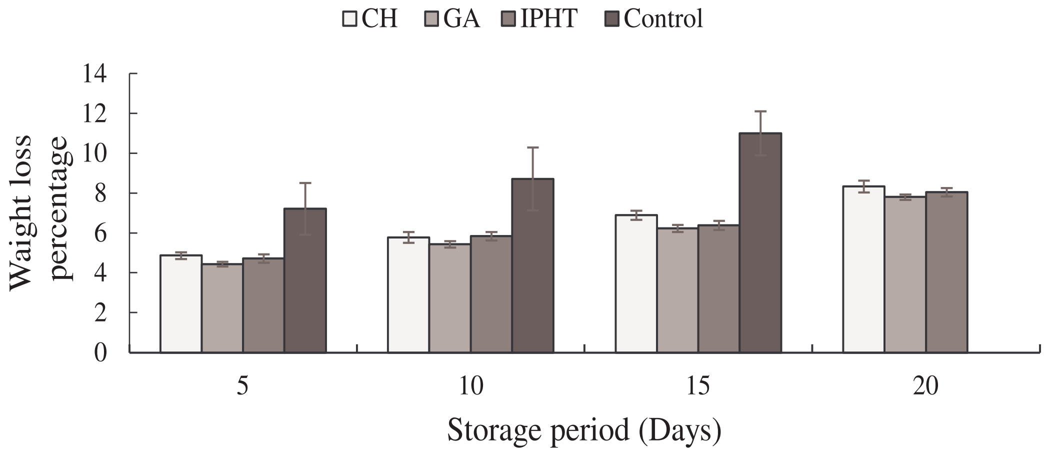

Figure 1: Effect of bio wax on weight loss of mango fruits during cold storage. CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT -IPHT bio wax 1:25. Vertical bars indicate standard error of means for five replicates.

Colour Measurements

Colour is an important factor in the perception of mango fruit quality. Figure 02 shows the changes in the surface colour of mango fruit, as indicated by lightness (L*). The peel colour of all the mangoes became the light yellow with storage time. L* values were significantly different ($P<0.05$) between control and treatments. Throughout the storage period, the chitosan treated fruits showed the lowest L* values and the fruits of control treatment had the highest values when compared with the other treatments (Figure 2). During the storage period, there was no significant difference ($P>0.05$) among Gum Arabic and IPHT bio wax treatments for the changes in the lightness of the fruits.

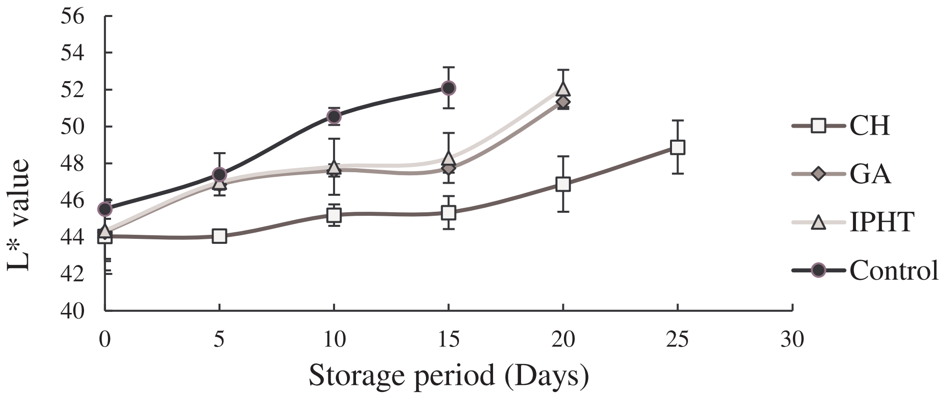

Figure 2: Effect of bio wax on L* value of mangoduring the storage period. CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT - IPHT bio wax 1:25. L* value: lightness, black (0) to white (100).

The 'a' value indicates the turning of fruits from green (-) to red (+). The change in a* value of the treated samples and control is shown in Figure 03. According to the results until the end of the storage period, there was no significant different ($p<0.05$) between Gum Arabic and IPHT bio wax treatments for the reduction in the green colour of fruits. Until the fifteenth day of storage life, there was no significant difference ($p<0.05$) among a* values of treatments as well as treatments and control fruits. After the fifteenth day of storage, there was a significant differ ence ($p<0.05$) between treated mango and control treatments. The reduction of green colour is lowest in Chitosan treated mango.

The 'b' values indicate the turning fruits from yellowness to blueness. Positive (+) values are towards yellowness while negative (-) values are towards blueness. The change in b* value of the treated samples and control is shown in Figure 05. There was a significant difference ($p<0.05$) between treated fruits and control sample in the fifteenth day of the storage period. In the twentieth day of storage, there was a significant difference between caducean treatment and other wax treatment. The disappearance of green pigment chlorophyll is associated with the appearance of yellow pigment carotenoids. These carotenoids are stable compounds which are synthesized during developmental stages but masked by the presence of chlorophyll. The results are in accordance with those of Doreyappy-Goda and Huddar who reported that the concentration of carotenoids was increased due to a series of physico-chemical changes in green mature mango. During ripening, skin colour changes are due to the breakdown of chlorophyll leading to the disappear nce of green colour.

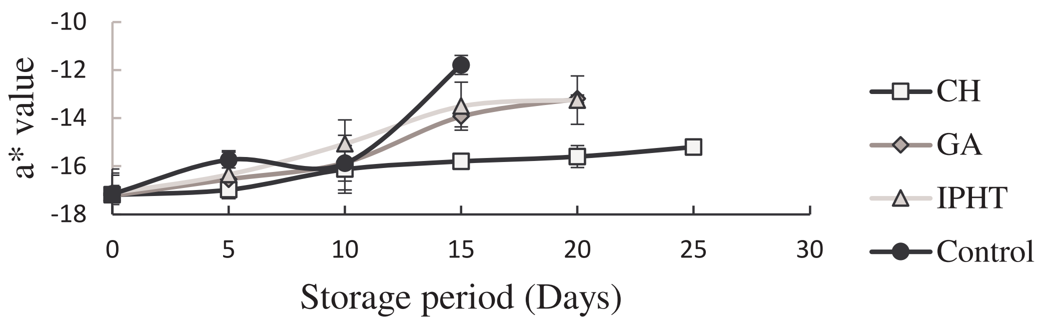

Figure 3: Effect of bio wax on the a* value of mango during storage period.CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT - IPHT bio wax 1:25. a* value: green (-) to red (+)

(-) to red (+)

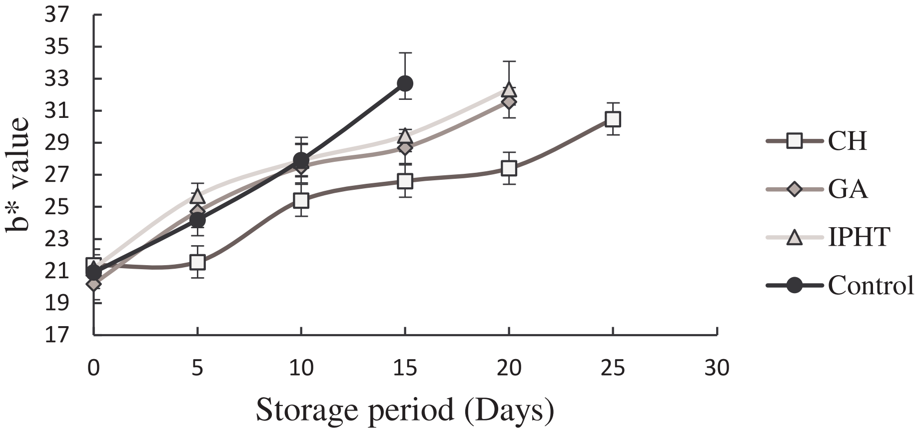

Figure 4: Effect of bio wax on the b* value of mango during the storage period. CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT - IPHT bio wax 1:25. b* value: yellowness to blueness.

Firmness

Ripening of mango fruit is considered by textural softening during storage. The firmness showed a decreasing pattern with the advancement of the storage period and the change being faster for untreated fruits than in any other treatments (Table 1). The faster changes observed from untreated control might be as a result of enhanced ripening that leads to early softening. Fruit softening is associated with the processes of solubilization of pectic substances; break down of starch to soluble sugars and loss of water from the peel (Mebratie *et al*., 2015). From day 10 up to the end of the experiment, treated mango significantly retained higher firmness over control fruits. Application of Chitosan was the most effective treatment resulting in higher firmness values throughout the storage period than all the other trea tments.

Kittur *et al*., (2001) confirmed that edible coating retained high firmness in mango. In this study, the fruits treated with chitosan 0.8% coatings showed more firmness than the control. These coatings might be created a modified atmosphere around the fruit surface as a result ofreduced changes in pectin substances and thereby delayed the textural changes.

The Total Soluble Solids Content

There was a significant difference ($p < 0.05$) in total soluble solids during storage due to the treatments. Total soluble solids content is a maturity index and also used for quality measurement. The ratio of sugar to acid plays a significant role in the determination of the ripening stage and taste of the fruit. Total soluble solids content gradually increased in all samples regardless of dipping treatments with increasing the storage time (Figure 5). From day 5 up to the end of the experiment, chitosan treated fruits significantly retained lower total soluble solids content than the other treatments (Figure 5). However, there was no significant difference (P>0.05)in total soluble solids content between gum Arabic 8% and IPHT bio wax 1:25. After 10th day of storage, wax treated fruits were lower in total soluble solids content when compared to the control treatment. These results revealed that Chitosan 0.8%, Gum Arabic 8% and IPHT bio wax 1:25 coating treatments efficiently reduced the rapid changes in total soluble solids content during the storage period. Edible coating created a semipermeable film around the fruit and modified the internal atmosphere by increasing CO_2 and decreasing O_2 production (Medeiros *et al*., 2012). The low respiration rate reduces the use of metabolites, resulting in lower total soluble solids content consumption and slow conversion of carbohydrates to sugars. A possible explanation for the lower total soluble solids content in mango

Table 1: Effect of IPHT bio wax, Gum Arabic and chitosan on firmness (N) of mango fruit during storage at 13°C for 20 days.

Treatments	**Storage period (days)**				
	0	**5**	**10**	**15**	**20**
Chitosan 0.8%	79.68±0.49a	74.14±0.18a	72.07±0.20b	71.73±0.31c	66.78±0.38b
IPHT bio wax 1:25	79.12±0.03a	73.31±0.32a	69.58±0.29ab	63.62±0.25b	56.47±0.25a
Gum Arabic 8%	83.62±0.87a	79.54±0.17a	76.34±0.19c	64.11±0.36b	59.85±0.14a
Control	78.71±0.44a	73.63±0.54a	65.65±0.19a	54.02±0.44a	*N/A

Means with the same letters within a column are not significantly different at P<0.05. Each value presents the mean ± SD of three replicates. * Fruits discarded due to over-ripening fruits treated with Chitosan 0.8%, Gum Arabic 8%, and IPHT bio wax 1:25 might be due to suppression of respiration and metabolic activity, thereby delayed the conversion of starch into sugars. Mango fruits treated with bio waxes reduced changes in total soluble solids content, thus these treatments retained the fruit quality and protected the fruits from quick deterioration during storage.

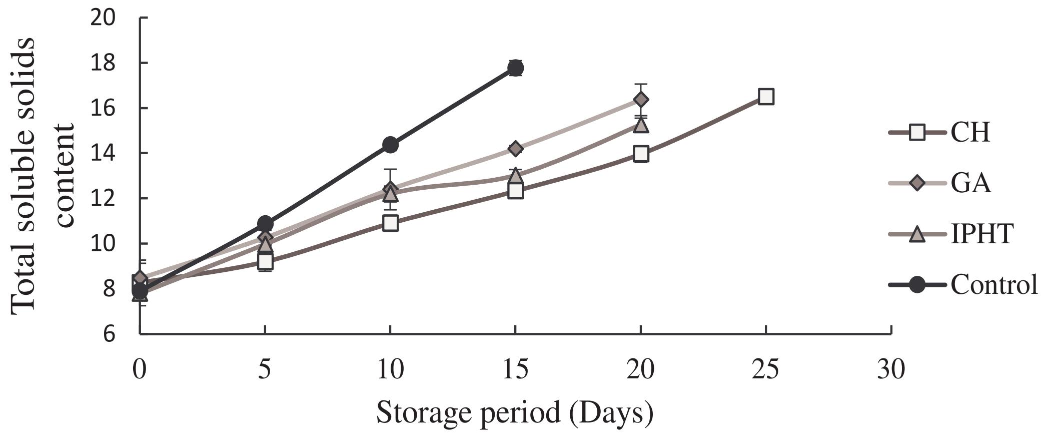

Figure 5: Changes in the Total soluble solids content during the storage period with treatments. CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT - IPHT bio wax 1:25.

Titratable Acidity and pH

There was a significant difference ($P< 0.05$) in fruit pH during storage compared with wax treatments to control treatment. The pH generally increased steadily over the storage period irrespective of treatments (Table 2). This could be due to degradation of organic acid during respiration as substrate. There was no significant difference ($P>0.05$)among the pH values of wax treated samples.

Titratable acidity was decreased significantly ($P<0.05$)during storage period in both coated and uncoated fruits (Figure 06). Results showed that lowest titratable acidity was found in control samples whereas highest in chitosan treated sample. A similar pattern in different varieties of mango fruits has been reported (Abbasi *et al.,* 2011). The obtained results showed that coatings slowed the changes in titratable acidity and effectively delaying fruit senescence. This was probably because the film formed by materials used on the surface of the fruit might have modified the internal atmosphere i.e., the endogenous CO_2 and O_2 concentration of the fruit, thus retarding ripening. The higher levels of titratable acidity observed in wax treated samples may be due to protective O_2 barrier or reduction of O_2 supply to the fruit surface which slows down the respiration rate, thereby it reduces the ethylene biosynthesis which delays the process of converting carbohydrates into sugars.

It was considered that 50% ripening stage as the end of storage life. Based on that, chitosan 0.8%, Gum Arabic 8%, IPHT 1:25 and control showed storage life of 27, 23, 24 and 18 days respectively.

Table 2: Effect of treatments on pH of mango fruit pulp during the storage period.

Treatments	**Storage period (days)**				
	0	**5**	**10**	**15**	**20**
Chitosan .08%	3.27±0.29a	3.41±0.15a	3.21±0.09a	3.33±0.10a	3.56±0.51a
IPHT bio wax 1:25	3.37±0.15a	3.31±0.04b	3.49±0.16a	3.78±0.34b	3.43±0.20b
Gum Arabic 8%	3.32±0.09a	3.56±0.24b	3.53±0.13a	3.39±0.15b	3.60±0.21b
Control	3.33±0.3a	3.77±0.14b	4.27±0.57b	4.24±0.69c	*N/A

Note: Means with the same letters within a column are not significantly different at P<0.05. Each value presents the mean ± SD of three replicates. * Fruits discarded due to over-ripening

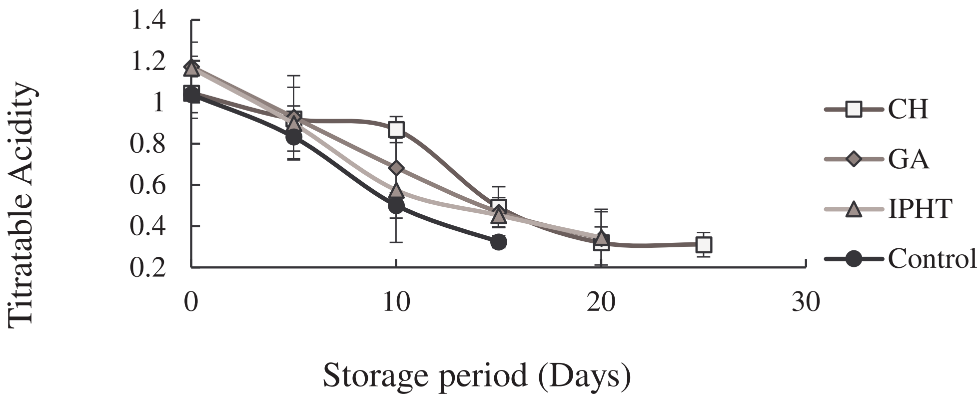

Figure 6: Changes of titratable acidity with the treatments during the storage. CH - Chitosan 0.8%, GA - Gum Arabic 8%, IPHT - IPHT bio wax 1:25.

Conclusions

The results of the current research indicated that the application of Chitosan, Gum Arabic and IPHT bio wax coatings delayed the ripening process and reduced physico-chemical changes of mango fruit during cold storage. Chitosan 0.8% treatment showed a significant ($P<0.05$) delay in the changes of weight loss, firmness, titratable acidity, total soluble solids content and colour of the fruits, compared with other two wax treatments and uncoated one. This study suggested that the application of bio wax coatings can be used for reducing post-harvest deterioration, extending the shelf life and maintaining the quality of mango cv. Karthakolomban fruits during cold storage. It was concluded that edible coatings of Chitosan 0.8%, Gum Arabic 8% and IPHT bio wax 1:25 have a good potential in maintaining the fruit quality and Chitosan 0.8% was the most effective treatment on all parameters tested for Mango cv. Karthakolomban.

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