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Efficacy of Beeswax and Essential Oil Coatings on Preserving Quality and Extending Shelf Life of Unripe Mangoes (*Mangifera indica*)

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Abstract

This study evaluated the performance of Mangifera indica *fruits coated with beeswax admixed with some essential oils including cinnamon, lavender and clove oil. Weight loss, colour change and some chemical analyses were used to adjudge the quality preservation and shelf life extension of the* Mangifera indica *fruits. The weight of* Mangifera indica *fruits coated with all the treatments decreased over the period of observation; however, fruits coated with beeswax admixed with lavender oil had the least weight loss (2.94%). The colour varied from green to yellow with black spots, where fruits coated with beeswax and beeswax admixed with lavender oil retained the pale green throughout the study. Also, there was a significant increase in pH and a decrease in titratable acidity (TTA) of samples in the control plot. The study therefore concludes that the edible coatings tested demonstrated great potential in maintaining the overall quality compared with untreated control. Beeswax mixed with lavender coating effectively delayed ripening of the* Mangifera indica *fruits for an additional 6 days as indicated by the reduction of weight loss, total titratable acidity and pH.*

Keywords: Beeswax, delayed ripening, edible coating oils, lavender, mango fruits

INTRODUCTION

In tropical nations, the mango tree (*Mangifera indica* L.), which is a member of the Anacardiaceae family, is extensively grown for its fruit (Tuo *et al.*, 2022). Because of its high nutritional value in the human diet, its fruit—which is categorized as a drupe—is particularly essential (Din *et al.*, 2021). Mangoes are rich in carbohydrates, proteins, lipids, minerals, and vitamins, especially vitamin A (beta carotene), vitamin B1, vitamin B2, and vitamin C (ascorbic acid) (Talcott *et al.*, 2005). They also have a great flavor and a pleasant scent. The fruit's pulp (mesocarp), skin, and seed (endocarp) are mostly consumed fresh or processed into various products such as sauces, juices, and squash (Aslam *et al.*, 2019; Din *et al.*, 2021). Sweet, juicy, and succulent, mango fruits are green while unripe but become green to light green or yellowish to reddish when mature (Shishir and Chen, 2017; Ojurongbe *et al.*, 2022). While ripe mango fruits are a wonderful source of vitamin A, thiamine, and other nutrients, unripe mango mangoes are high in vitamin C. They are a genuine source of energy because they also contain sugar (Zafar and Sidhu, 2017). According to Alam *et al.* (2016), mangos are a great source of bioactive compounds that can slow down the aging process, enhance lung function, lower the risk of some types of cancer, and lessen the difficulties that come with diabetes.

Despite its many nutritional and physiological advantages, mango fruits are extremely sensitive and perishable due to their quick ripening phase and inadequate post-harvest treatment. Additionally, this makes the fruits more vulnerable to microbial attack, which lowers their quality and shortens their shelf life. Because of the quick ripening, the fruit's physicochemical and organoleptic qualities change, necessitating fruit preservation to increase shelf life and improve fruit quality (Désiré *et al.*, 2023). The usage of edible coating has gained popularity recently among the several technologies used to prolong the shelf life or maintain the quality of fruits and vegetables. An alternative to chemical agents or artificial preservatives that endanger the health of customers is edible coating. Additionally, it inhibits microbial development, oxygen penetration into plant tissues, and the loss of moisture and aroma (Ding and Lee, 2019; Nor and Ding, 2020). This study, therefore, aims to preserve and delay ripening during the storage of mango fruit using beeswax and some essential oils (cinnamon, lavender, and clove oil).

MATERIALS AND METHODS

Materials

The materials for this study were beeswax, clove oil, cinnamon oil, lavender oil, and mango.

Methods

Purchase of beeswax, essential oils and mango

Beeswax were purchased from Bodija Market, Ibadan, Oyo state. While the following essential oils (clove, cinnamon, and lavender) were ordered from a renowned essential oil store. These oils were selected based on their antimicrobial potential (Nasrin *et al.*, 2020)

Thirty (30) pieces of freshly harvested matured unripe mango from a field plot at the Nigerian Horticulture Research Institute, Ibadan, were purchased and sorted based on colour, size, and absence of external injuries. The sample size was selected so that it will be enough for destructive sampling for the analysis period. The washed fruits were sanitized by dipping in 0.1% (v/v) Sodium hypochlorite (NaOCl) solution for 30 s and air-dried under an electric fan before the application of coating. Each sample was subjected to total immersion into the oil to ensure uniformity of the oil around the fruits and placed on the workbench at room temperature.

Preparation of Beeswax-loaded essential oil

Beeswax-incorporated essential oils were prepared according to the modified method described by Lakshan et al. (2024). Beeswax was dissolved by heat, and the solution of beeswax was stirred at 25°C to have a uniform mixture. After getting a homogeneous mixture, the oil was gradually dropped into the prepared Beeswax solution to obtain an oil-in-water emulsion with a mass ratio of essential oils of 10:1 (v/v).

Application of Beeswax-essential oil

Twenty-four pieces of mature unripe mango were divided into 4 groups (each group containing 6 pieces of mango). The control group, beeswax group, beeswax + clove oil group, beeswax + cinnamon oil group and beeswax + lavender oil group at a ratio of 10:1. The formulated edible coatings were applied to mango using dip coating method, which involves immersing of fruits into their corresponding coating materials for 3 seconds after which the samples were placed in stackable crates at room temperature for monitoring of physical and chemical activities for 7 days.

Physical observation

Physical observation includes; weight loss and observable physical change of colour.

Weight loss

The percentage of weight loss in control and coated was measured during 4 weeks of storage using an electronic balance (GE812, Sartorius, Germany). All groups were in triplicate. The percentage of weight loss for each treatment was calculated according to the method of Fawole and Opara (2013).

Colour

The epicarp colour change of the mangoes was estimated using the description of Oyewole *et al.* (2023) in Table 1 below.

Table 1: Mango fruits Epicarp Colour Description

Ripening Stage	Peel Colour Description	Ripening Physiological Phase
1	Green	Pre-climacteric
2	Pale green	Pre-climacteric
3	Pale green with yellow tip	Onset to climacteric
4	Yellow: Green - 1: 1	Climacteric
5	More yellow than green	Climacteric
6	Pure yellow (purely ripe)	Climacteric
7	Yellow with black specks (senescent spot developing)	Onset to senescence
8	Yellow: Black (1: 1)	Senescence
9	More black than yellow	Senescence

Source: Oyewole *et al.*, 2023.

Chemical Analysis

Moisture Content/Dry Matter Determination

Moisture content was determined using the air oven method described in AOAC (2010). Crucibles were washed and dried in an oven. They were allowed to cool in the desiccator and the weight was noted. A known weight of samples was transferred into the crucibles and dried at a temperature between 103-105 °C. The dried samples were cooled in a desiccator and the weight was noted. They were later returned to the oven, and the process continued until constant weights were obtained.

Calculation:

$$Moisture\ Content\ \% = \frac{(Weight\ Loss)}{(Weight\ of\ Sample)} X\ 100$$

Dry matter = 100- Moisture content

Total soluble solid, Titratable Acidity, and pH

To evaluate Total Soluble Solid (TSS), TTA, and pH, the method described by Ghasemnezhad *et al*. (2011) was used. A refractometer (Refractometer Abbe, Bellingham & Stanley Ltd, UK) calculated TSS in control and coated treatments, and data was expressed as °Brix. A pH meter was used for measuring pH. TTA was calculated by titrating 5 mL of juice to reach the endpoint of pH 8.2 with 0.1 N NaOH and recording the titration volume. The resulting data was expressed as a citric acid percentage. All measurements were done in triplicate.

Total Sugar

The total sugar was carried out using the Lane-Eynon method for total sugar described (Pereira dos Santos *et al*., 2019). The titration method evaluates the concentration of reducing sugars in the sample based on their reducing action towards certain metallic salts. The sample reduces copper sulfate in an alkaline tartrate system (Fehling's solution).

Statistical analysis

One-way analysis of Variance (ANOVA) was done through IBM SPSS Statistics version 23 (IBM Corporation, USA). Duncan's multiple range tests were used to determine the statistical differences among the mean values of various treatments with a 95% significance level.

RESULTS

Effect of beeswax and edible oils on weight performance of mango fruits.

The weight performance of mango fruits coated with beeswax only and beeswax admixed with edible oils (clove, cinnamon, and lavender oils) were significantly different ($p < 0.05$) across the six days of observation (Table 2). Similar trend of decrease in weight was observed across all the days of sampling except at day 6, where the weight increased for the control plot and the plot coated with beeswax + cinnamon oil and the plot coated with beeswax + clove oil. Samples coated with beeswax + lavender oil had the lowest weight loss (2.94%) while beeswax + cinnamon oil recorded the highest (9.39%). The weight loss recorded on samples coated with beeswax only and the control were the same (6.73%).

Table 2: Mean weight (g) of mango fruits coated with beeswax and three essential oils

Treatment	Baseline	Day 2	Day 4	Day 6	Weight loss %
Bx	225.23 ± 105.19	220.46 ±101.24	215. 32 ± 55.85	210.87 ± 96.55	6.73
BxCl	212.93 ± 68.42	200.66 ± 68.51	195.46 ± 68.74	197.35 ± 68.88	7.32
BxCn	194.70 ± 30.79	182.43 ± 25.64	171.67 ± 20.82	176.42 ± 18.54	9.39
BxLv	208.88 ± 50.0	205.68 ± 48.55	204.81 ± 46.23	202.75 ± 45.40	2.94
Control	203.50 ± 59.26	191.23 ± 57.46	180.85 ± 55.85	189.8 ±56.76	6.73

Bx = Beeswax only, BxCl= Beeswax+ Clove oil, BxCn= Beeswax+ Cinnamon oil, BxLv= beeswax + lavender oil

Effect of beeswax and edible oils on colour changes of mango fruits.

The result indicated that there were colour changes on the mango fruits from yellow to black spot across the days of observation (Table 3). The colour change was consistent for samples coated with beeswax + lavender except at day 6, where there was a little change from green to pale green. A similar trend was observed with samples coated with beeswax, cinnamon oil, and clove oil, where the colour changed from green to pale green and yellow tips. The samples in the control plot had a drastic colour change from green to yellow with a black spot within the days of observation.

Table 3: Colour variation of mango fruits coated with beeswax and three essential oils

Treatments	Baseline	Day 2	Day 4	Day 6
Bx	1	1	2	2
BxCl	1	2	2	3
BxCn	1	2	3	3
BxLv	1	1	1	2
Control	1	3	5	7

Where; Bx= Beeswax only, BxCl= Beeswax and Clove oil, BxCn= Beeswax and Cinnamon oil, BxLv= Beeswax and Lavender oil

1-Green; **2**-Pale green; **3**-Pale green and yellow tips; **4**-Yellow; **5**-More yellow than green **6**-pure yellow **7**-Yellow with black spot **8**-Yellow; black; **9**-More black than yellow

Effect of beeswax and edible oils on dry matter of mango fruits.

The mango fruits' dry matter decreased over the evaluation period for all the treatments except samples coated with beeswax, cinnamon, and lavender oils, where increase was observed at day 6 (Table 4). Samples coated with beeswax only recorded the least percentage dry matter loss (3.38%), followed by beeswax with lavender (8.30%) while the highest was recorded on beeswax and clove (25.67%).

Table 4: Dry matter of mango fruits coated with beeswax and three essential oils

Treatment	Baseline	Day 2	Day 4	Day 6	Dry matter loss %
Bx	73.23 ± 1.32	72.30 ± 1.28	71.0 ± 1.25	70.75 ± 1.23	3.38
BxCl	77.41 ± 1.12	70.21 ± 1.30	63.24 ± 1.42	57.54 ± 1.52	25.67
BxCn	72.29 ± 1.23	60.24 ± 1.42	51.40 ± 1.64	59.28 ± 1.84	17.99
BxLv	74.37 ± 1.43	70.21 ± 1.80	65.46 ± 2.21	68.16 ± 2.62	8.30
Control	74.0 ± 0.25	65.0 ±0.44	60.36 ± 1.02	57.01 ±1.14	22.97

Values are expressed in mean ± standard error of mean (n=3)
Where; Bx= Beeswax only, BxCl= Beeswax and Clove oil, BxCn= Beeswax and Cinnamon oil, BxLv= Beeswax and Lavender oil

Effect of beeswax and three essential oils on the pH and Total Titratable Acid of mango fruits

The pH value of mango fruits in Figure 1 below shows that the normal control significantly increased across the days of observation. The plots coated with beeswax mixed with clove, beeswax mixed with cinnamon, and normal control shows higher pH value than other treatments at 6 days post-treatment.

The Total titratable acid (TTA) of mango fruits, Figure 2, recorded a significant decrease in the normal control group at day 2, 4, and 6 post-treatment. No significant difference ($p<0.05$) was observed in plots treated with beeswax only and beeswax mixed with lavender at 2 days post-treatment. The highest TTA was recorded in the plot coated with beeswax mixed with lavender 6 days post-treatment.

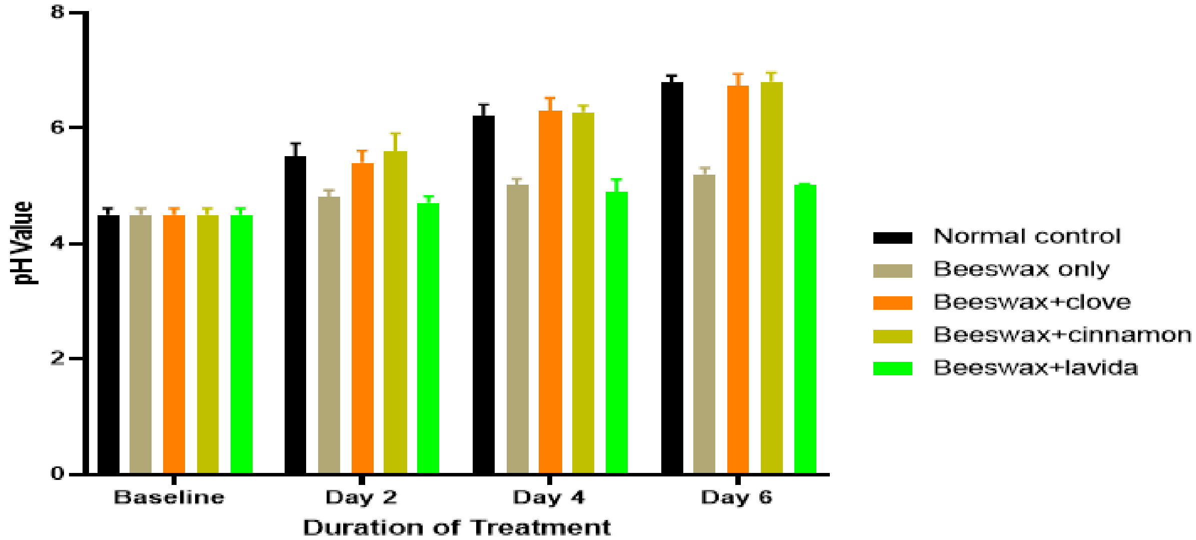

Figure 1: Variation in pH level of mango fruits coated with beeswax and three essential oils

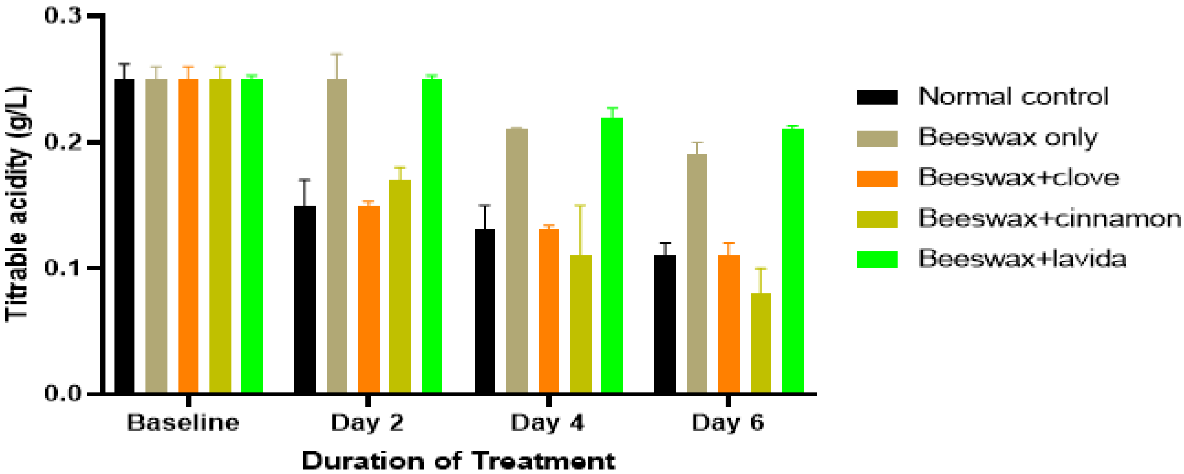

Figure 2: Total titratable acidity of mango fruits coated with beeswax and three essential oils.

DISCUSSION

This study validates the use of edible coating materials for the preservation and shelf life extension of mango fruits, where ripening was delayed in mangoes coated with beeswax + lavender oil for 6 days. According to Hosseini (2023), the use of beeewax is well known for preservation of fruits. The weight status of all the treatments followed the same pattern of decline with the advancement of the storage period except on day 6, when three treatments had an abrupt increase. This might be the result of the fruit surfaces' hygroscopic state combined with a sudden increase in the relative humidity of the surrounding air. The findings also show that the combination of beeswax and lavender oil reduced the mangoes' percentage weight loss during storage the best. This could be explained by the higher viscosity of lavender oil and the hydrophobic nature of beeswax (Eshetu *et al.*, 2019). Together, these properties act as a barrier against respiration, the transfer of water vapour, and other molecules between the mangoes' internal and external environments (Pereira dos Santos *et al.*, 2019). Hoa *et al.* (2002) found similar outcomes, demonstrating that wax coating lowered respiration and transpiration rates, reducing weight loss and shrivelling while extending shelf life.

The results on colour change show a similar trend. With the exception of beeswax and lavender oil, which only saw a little colour change (2), all of the treatments underwent gradual modifications. On the sixth day of storage, the colour change in the control group reached its maximum (7). It is claimed that variations in fruit colour during storage are related to the synthesis of pigments such as carotenoids. It will make sense to connect the thickness of the coating material, which prevents gaseous exchange across the fruit's skin with the delayed colour changes in coated fruits, if the prior explanation of the semi-permeability of beeswax coating and oil viscosity is any indication. As a result, the activity of the enzymes needed to synthesise carotenoids would decrease (Eshetu *et al.*, 2019), delaying the synthesis of carotenoids (Ullah *et al.*, 2017). This might have caused the little hue shift that was seen after applying the beeswax and lavender oil treatment. Similar conclusions were reached by Mladenoska (2012) and Nasrin *et al.* (2020), who discovered that beeswax coatings containing coconut oil improved the look of strawberries and lemon fruits. The study also shows how the coatings affected the mango's titratable acidity. The treatments resulted in a substantial difference ($p < 0.05$) in the titratable acidity of the fruit during storage. Cinnamon combined with beeswax has the least titratable acidity. The control treatment came next, with beeswax + lavender having the highest titratable acidity. According to Tefera *et al.* (2008), the various coating materials may have had differing effects on the fruits' rate of respiration and, consequently, on how quickly they used respiratory substrates such as organic acids. The little depletion of organic acids and prevention of the growth of acid-producing microbes in the treated mangoes may have been caused by the beeswax + lavender coating, which also slowed the increase in titratable acidity (Ajibola *et al.*, 2023). The treatments also resulted in a substantial variation ($p < 0.05$) in the pH of the fruit during storage.

Mangoes without coating had the highest pH value, while those coated in beeswax and lavender had the lowest pH value at the conclusion of storage. Regardless of treatments, the pH generally rose gradually throughout the course of the storage period. This might result from organic acid breaking down as a substrate during respiration. These results are consistent with those of Wani *et al*. (2014), who found that overall acidity may decrease during the ripening phase or storage period and increase fruit pH. Moreover, compared to the control group (22.97%), mangoes coated with beeswax and lavender may have experienced the least dry matter loss (8.30%) due to the delayed substrate depletion.

CONCLUSION

The study concludes that beeswax and lavender oil exhibit great potential in extending the shelf life of mango fruits by 6 days. There was also a slight change in the pH value (4.88 - 5.0) and the titratable acidity (TTA) (0.26 – 0.24 g/L). These can, therefore, enhance the post-harvest quality and longevity of the fruit.

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Conflict of Interest:

The authors declare that they have no conflict of interest.

Declaration of competing interest

The authors declare that no part of the manuscript reporting original work is being considered for publication in whole or elsewhere.

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