



Effect of *Manihot esculenta* Edible Coating Blended with African Basil (*Ocimum gratissimum*) Essential Oil on the Shelf-Life of Mango Fruits

Decrah M. Nyangena^{1,2*}, Phanice T. Wangila³ and Jackson K. Cherutoi¹

¹Department of Chemistry and Biochemistry, School of Sciences and Aerospace Studies, Moi University, P.O. Box 3900-30100, Eldoret, Kenya.

²Africa Centre of Excellence in Phytochemicals, Textile and Renewable Energy (ACE II PTRE), Moi University, P.O. Box 3900-30100, Eldoret, Kenya.

³Department of Physical Sciences, University of Kabianga, P.O. Box 2030, Kericho, Kenya.

Authors' contributions

The work was done in collaboration among all authors. Author DMN collected the samples and performed laboratory analyses. Author DMN wrote the first draft of this manuscript. Authors PTW and JKC supervised, revised and approved the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJACR/2021/v9i430219

Editor(s):

(1) Prof. Angélica Machi Lazarin, State University of Maringá, Brazil.

(2) Prof. Endang Tri Wahyuni, Gadhah Mada University, Indonesia.

Reviewers:

(1) Ioana Stanciu, University of Bucharest, Romania.

(2) Aymn Yaseen Sharaf Zeebaree, Duhok Polytechnic University, Iraq.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/75314>

Original Research Article

Received 01 August 2021

Accepted 08 October 2021

Published 08 October 2021

ABSTRACT

Aims: To establish the shelf -life of mango fruits coated with unmodified and modified *M. esculenta* edible coating at low ($4 \pm 2^\circ\text{C}$) and room temperature ($23 \pm 2^\circ\text{C}$) conditions.

Place and Duration of Study: The study was done at Moi University, School of Sciences and Aerospace studies, Department of Chemistry and Biochemistry between January 2021 and June 2021.

Methodology: *Ocimum gratissimum* leaves essential oils was obtained by hydro-distillation method using Clevenger apparatus. Preparation and modification of the coating were homogenized at $70 \pm 2^\circ\text{C}$. Physico-chemical parameters including weight loss, titratable acidity (TA), Vitamin C concentration, total soluble solids (TSS), and pH were used to establish the fruits' shelf-life.

*Corresponding author: Email: decrahmoraa@gmail.com;

Results: The modified *M. esculenta* (cassava) starch coating (1.5%) treatment, their interactions and storage duration significantly affected the physico-chemical parameters of mango fruits. The modified coating-maintained TA 0.66%, 0.87%, reduced weight loss by 27.81%,14.62%, delayed the increase of TSS 7.50%, and pH 5.20, 4.93 while retaining the vitamins C 8.13 mg/100g, 15.09mg/100g concentration up to eighteen days and twenty-seven day of storage at $23 \pm 2^\circ\text{C}$ and $4 \pm 2^\circ\text{C}$ respectively. The distilled water treatment (control) reduced TA to 0.11%, 0.23%, increased weight loss to 47.12%, 24.21%, TSS 20.22%, 17.41%, and pH 8.21, 5.20 while retaining the vitamin C 3.74 mg/100 g, 8.13 mg/100 g concentration at $23 \pm 2^\circ\text{C}$ and $4 \pm 2^\circ\text{C}$ respectively.

Conclusion: Results of the present study showed that *M. esculenta* edible coating incorporated with *O. gratissimum* essential oil extended the shelf life of mangoes up to eighteen and twenty-seven days of storage at room temperature ($25 \pm 2^\circ\text{C}$) and low temperature ($4 \pm 2^\circ\text{C}$), respectively. This treatment might be an effective farm-based post-harvest treatment in prolonging the shelf life of fresh produce while maintaining their physico-chemical parameters.

Keywords: Post-harvest losses; *Manihot esculenta*; Edible coating; Mangoes; *Ocimum gratissimum*.

1. INTRODUCTION

Post-harvest losses have been a concern for quite some time both in the developed and developing world [1]. Fruits are key to human nutrition and minimizing their post-harvest loss may improve the shelf-life of fruits as well as their quality while preserving active constituents for use by its consumers. The bio packaging materials will play a key role in reducing rotting as they provide antibacterial, antioxidant and antifungal activities [2]. The interest in biodegradable edible films/coating in recent decades can be explained by consumer demand for high quality foods, health factors and environmental concerns over the disposal of non-renewable food packaging materials, and opportunities for creating new market outlets for film forming ingredients derived from agricultural products [3]. Biotechnological production of polymers has been through fermentation of microorganisms in stirred bioreactors or produced by in vitro enzymatic processes. However, the largest amounts of biopolymers are still extracted from plant and animal sources. Biopolymers exhibit fascinating properties and play a major role in the food processing industry, for instance, modifying texture and other properties. Among the various biopolymers, polysaccharides and bioplastics are the most important in the food industry [4].

The application of edible films/coating for food preservation dates back to the 12th century when wax was being utilized in china to preserve fruits and vegetables [5]. Later, on the 19th century, an edible coating made from sucrose was utilized on dry fruits and nuts to deter enzymatic oxidation and rancidity throughout the storage periods [6]. Fruits and vegetables have since been coated

with various emulsions to improve the appearance, shininess, color, and gloss to impress the customers or consumers [7]. Literature reports that edible films and coatings are quite beneficial in that they are consumable and easily biodegradable [8]. Secondly, they improve the quality of food products, guarding them from mechanical and physical injuries, invasion of pathogens, moisture migration and oxidation of nutrients and importantly extending the shelf life of food [9]. Additionally, most edible films and coatings have been reported to enhance the quality of food product by acting as barriers against gases, oils and as a carrier of active substances such as antioxidants and antimicrobials [10]. Edible coatings can be formulated from a wide array of food-grade biopolymers. These biopolymers can be based on proteins, waxes, lipids, polysaccharides and resins or combination [4]. These edible films can be used as capsules, wraps, pouches, bags or casing after being subjected to further modifications [11].

Starch, another polysaccharide, is widely used in industry to provide functional properties such as gelling, thickening, bonding and adhesion in food products, and has been extensively used in edible coating preparations [12]. Starch from various sources can present different amylose/amylopectin ratios that can induce distinct edible coating properties [13]. In view of these aspects, blends of starch and oils can provide an interesting behavior which needs to be investigated in order to allow its applicability [14]. The edible films designed for the particular product must be well-suited with that particular product. Falguera et al., [15] reports that for the film-forming process to auger well with the intended functions, certain fabrication conditions

have to be considered those are; pH modification, salt addition, heating, enzymatic modification, drying, use of food-grade solvents, or reactions with other food-grade chemicals. Currently, application of edible films has received a lot of interest in preserving a wide array of food such as, nuts, fruits, vegetables, candies and animal products [16]. The use of edible coatings such as cassava starch blended with natural plant extracts has also been embraced in preservation of pineapples [17], guavas [18], apple slices [19], and Martha tomatoes [20]. Its application resulted in delays in weight loss, total soluble solids, titratable acidity, firmness, decay and color during storage period at room temperature compared to the uncoated fruits [17,18,19,20].

In reducing negative environmental impacts and improving the novel food packaging industry as well as minimization of post-harvest food losses, edible coating composed of essential oils and *M. esculenta* (cassava) starch were prepared via a casting method. The aim of this study was to establish the shelf-life of mango fruits coated with unmodified and modified *M. esculenta* edible coating during refrigeration ($4 \pm 2^\circ\text{C}$) and at room temperature ($23 \pm 2^\circ\text{C}$) conditions.

2. METHODOLOGY

2.1 MATERIALS

Cassava starch prepared locally (Eldoret Kenya), was used as coating biopolymer, Analytical grade glycerol (Sigma Aldrich, USA) was used as a plasticizer, *Ocimum gratissimum* leaves was obtained from (Uasin-Gishu county, Kenya), potassium iodide, potassium iodate, sulphuric acid, sodium thiosulphate, starch indicator, Phenolphthalein indicator, sodium hydroxide was acquired from Sigma Aldrich, USA.

2.2 Study Location

The mature mango fruits at green stage were harvested in the morning hours from small holder farmers in Elgeyo- Marakwet, Kenya ($0^\circ58'55.0''\text{N}35^\circ35'15.5\text{E}$). They were packed in a large container lined with pricked paper, transported to Moi university chemistry lab for preparation.

The (*Ocimum gratissimum* Leaves were handpicked, cassava tubers by digging them up from the ground with a sterilized hoe. The collected parts were kept in clean separate sterilized manila bag after which they were

carried to the laboratory (Chemistry Laboratory at the Department of Biological Sciences) for sample preparation.

2.3 Equipment

NorLake refrigerator (M2PH-0026-IAA-121), Digital bench refractometer, weighing balance (Mettler- Toledo) model, digital pH meter (Sr. No 1630) model, Clevenger apparatus, heating mantle.

2.4 Experimental

2.4.1 Preparation of *O. gratissimum* essential oils

Ocimum gratissimum leaves essential oils was obtained by hydrodistillation method using Clevenger apparatus. About 100g of fresh pulverized *O. gratissimum* leaves was put into the hydro distillation unit and distilled for two hours. The obtained essential oils were dried over sodium sulphate and stored at 4°C in amber bottles until use.

2.4.2 Preparation of cassava (*M. esculenta*) starch edible coating

This was done following literature methods [1]. Cassava-starch coating suspension was prepared by dissolving 30 grams of cassava-starch in 1L of distilled water. The starch solution was stirred at 70°C until it completely dissolved. After, the solution was left to cool at room temperature and then 5 mL of glycerol was added as a plasticizer. This was followed by the addition of 1.5% (v/v) of *O. gratissimum* essential oils to the formulations to yield the modified coating.

2.4.3 Fruit coating

The fruit coating process was carried out following the procedure described by Botelho et al., [1] with slight modification. The selected fruits were randomly divided into six batches (180 fruits), 30 fruits for each batch to embrace the treatments: (Control (C), cassava *M. esculenta* starch (CS) and *M. esculenta* starch modified with 1.5% *O. gratissimum* oil (CS+EO) subsequently, the fruits of treatments CS and CS + EOs were immersed in the coating gels for 30 minutes; the excess was removed and, after drying for 10 min, the procedure was repeated in all batches. The fruits were then air-dried on trays, keeping a minimum distance of 2 cm

between the fruits. After drying, 3 batches of fruits were stored at room temperature condition of (23 ± 2°C), and 3 other batches at low temperature condition of (4 ± 2°C) and evaluations was performed/monitored at intervals of 3 days until spoilage.

2.4.4 Assessment of physico-chemical parameters of mango fruits

2.4.4.1 Determination of weight change

Three fruits from each batch of 30 mangoes were marked and individually weighed before storage commences. The fruits were subsequently weighed after 3 days sampling interval date to track their weight changes for the entire experiment. Weight measurements was taken by weighing balance and their averages determined in order to compute the overall weight changes. Percentage weight change/loss was calculated using the Formula 1.

$$WL = \frac{(WI-WF)}{WI} \times 100 \quad (1)$$

Where WI was the weight loss (%), Wi (g) and Wf (g) are the initial and final weights of mango fruits respectively [21].

2.4.4.2 Determination of concentration of ascorbic acid in mg/100g

Fifty (50) mL of the sample solution were pipetted into a 250 mL volumetric flask. Two (2) g of KI was added. Ten (10) mL of 0.5 M H₂SO₄ and 0.01 M potassium iodate solutions were then added into the flask simultaneously. The solution was then titrated immediately with 0.07 M sodium thiosulphate until the entire color gets almost pale yellow. Two (2) mL of starch indicator was then added and the titration process completed. The procedure was replicated twice for all the samples. The titer values were obtained and their means calculated to get the concentration of vitamin C in the samples [22].

2.4.4.3 Analysis of the total soluble solids (° Brix)

This was determined by use of a digital bench refractometer (range 0–32%). Before taking readings, it was standardized with distilled water and adjusted to reading 0 ° brix. Pulp tissue (10 g) was homogenized in 50 mL distilled water in the blender jug, and filtered with cotton wool. Then, two drops of the filtrate were placed on the glass prism of the refractometer and the reading

was recorded. This was done on three replicated samples solutions and the refractometer was then calibrated afresh using distilled water prior to use for the next sample [23].

2.4.4.4 Determination of titratable acidity

Ten (10) mL of the various prepared mango sample solutions were transferred into a 250 mL conical flask by a pipette. An equal amount of distilled water was added into the flask. Phenolphthalein indicator (3–4 drops) was then added and the solution stirred. The contents were rapidly titrated with 0.1 N NaOH solution and the end point determined when there was a definite color change from pink to colorless. The final burette reading was then noted and the calculation of titratable acidity was done using the following Formula 2 [22].

$$\% \text{ Acid} = (\text{NaOH used (mL)} \times 0.064) / (\text{grams of Sample}) \times 100 \quad (2)$$

2.4.4.5 Determination of pH

The pH of the sample solutions was measured using digital pH meter. Ten (10) mL of freshly prepared samples were placed in a beaker. The electrode end of the pH meter was used to agitate the solution until a stable reading was obtained. This was done on the three batch-samples of the same solutions respectively. Between readings the electrode was rinsed with distilled water to eliminate cross-contamination [23].

2.5 Statistical Analysis

The data obtained from the experiments above were expressed as means ± standard deviations and subjected to statistical analysis using Microsoft excel (Microsoft corporation, USA). Means were analyzed for significance difference by one-way analysis of variance (ANOVA) at 95% confidence interval with turkey post hoc test.

3. RESULTS AND DISCUSSION

3.1 Effects of *M. esculenta* Coating and Storage Period on Weight Loss of Mangoes

The *M. esculenta* (cassava starch) coating treatments, significantly affected weight loss of mango fruits subjected to room temperature (23

$\pm 2^{\circ}\text{C}$) and low temperature ($4 \pm 2^{\circ}\text{C}$) conditions. In this study, weight loss of all fruit samples increased progressively with the advancement of storage period. The control (T_0) fruits at room temperature condition demonstrated higher weight loss compared ($P= .03$) to the coated fruits, unmodified (T_1) and modified (T_2) (Fig. 1). The mango fruits stored at low temperature ($4 \pm 2^{\circ}\text{C}$) condition, the control (L_0), unmodified coating (L_1) and modified coating (L_2) showed weight loss which was relatively lower compared ($P=0.02$) to those of room condition ($23 \pm 2^{\circ}\text{C}$) (Fig. 2).

On the 9th day of storage, control (T_0), unmodified (T_1), and modified (T_2) recorded $26.53 \pm 0.02\%$, $20.97 \pm 0.01\%$ and $16.30 \pm 0.02\%$ weight loss respectively with a subsequent increase up to 18th days of storage (Fig. 1). On the 18th days of storage control (T_0), unmodified (T_1), and modified (T_2) recorded $47.12 \pm 0.02\%$, $34.01 \pm 0.01\%$, and $27.81 \pm 0.02\%$ respectively. Similarly, the control (L_0), unmodified (L_1) and modified (L_2) respectively recorded $11.72 \pm 0.02\%$, $8.05 \pm 0.02\%$ and $4.93 \pm 0.01\%$ weight loss and the trend increased steadily up to the 27th days of storage (Fig. 2). On the 27th day the control (L_0), unmodified (L_1) and modified (L_2) respectively recorded $24.21 \pm 0.02\%$, $19.82 \pm 0.02\%$, and $14.70 \pm 0.01\%$.

This result was comparable with literature work by [24], who reported an increasing weight loss

from the initial day to a maximum of 12 days. The weight loss for the control fruits indicated a maximum of 26.41% weight loss on the 12th day, compared to mangoes coated with olive 17.95% and chitosan 1% 7.53%. Another study by [21] reported that, weight loss increased with the advancement of storage period and reached the maximum on the 10th day for the control and the 15th day for the treatments, after which the mangoes were spoilt, respectively. Also, the study work by [25], on guar-based edible coatings blended with *Spirulina platensis* and *Aloe-vera* extract on mango recorded a highest 14.33% weight loss at the end of storage period compared to 6.8% the coated sample.

Manihot esculenta edible coating significantly affected weight loss and hence the shelf life of the coated mangoes was prolonged compared to the control. The progressive loss of water through evaporation from the fruit surface occurred as a result of normal metabolic processes such transpiration owing to the water vapor pressure difference between the atmosphere and the fruit surface which leads in shrinking and deterioration of the fruits [26]. However, the percentage

weight loss was more intense in the control fruits compared to the coated fruits. This is as a result of higher moisture loss and increased respiration through uninterrupted atmospheric column and lower relative humidity compared to the coated ones [9].

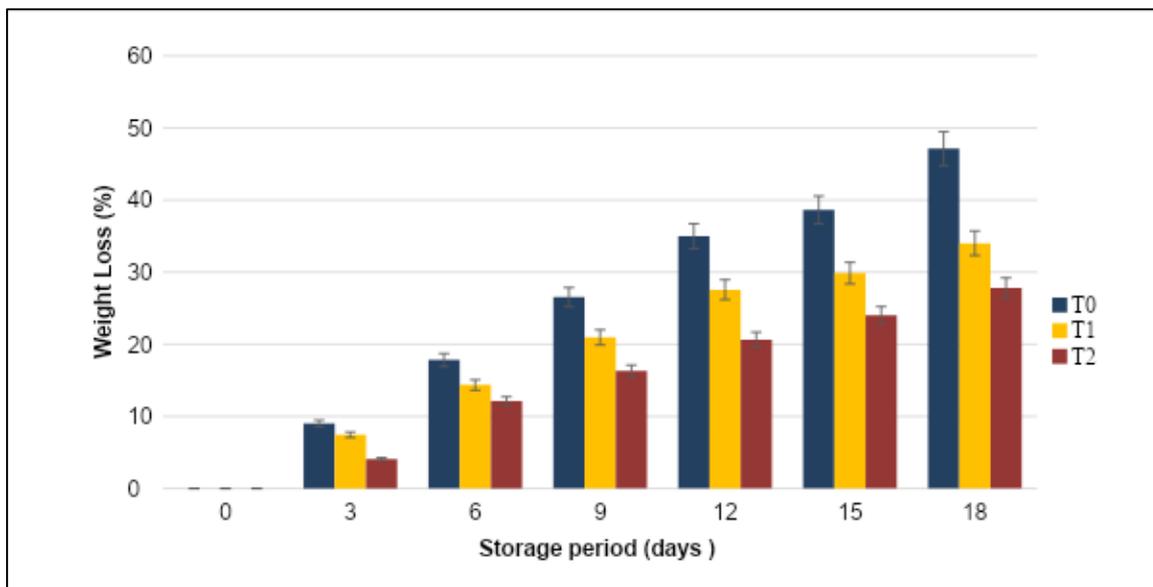


Fig. 1. Effect of different *M. esculenta* (CS) coating treatments on the weight loss of mango fruit during storage at room temperature ($23 \pm 2^{\circ}\text{C}$)

The reduced weight loss among coated fruits occurred as a result of the creation of a semi-permeable barrier which blocks the stem end scar from losing moisture, oxygen, and carbon dioxide subsequently reducing respiration and transpiration processes [27]. Moreover, the modification of edible coating with essential oils increased their functionality by creating a more complex matrix with antioxidant, and antibacterial properties [20].

3.2 Total Soluble Solids (TSS ° Brix %)

The *M. esculenta* (cassava) starch coating treatment significantly influenced the pulp TSS of mango fruits subjected to room temperature ($23 \pm 2^\circ\text{C}$) and low temperature ($4 \pm 2^\circ\text{C}$) conditions. The amount of the pulp TSS increased in all fruit samples during the 18th and 27th days of storage at room temperature ($23 \pm 2^\circ\text{C}$) (Fig. 3) and at low temperature ($4 \pm 2^\circ\text{C}$) conditions (Fig. 4) respectively. The TSS for the control (T_0) increased drastically ($P= .01$) from initial day $5.81 \pm 0.03\%$ and was highest on the 6th day of storage $20.20 \pm 0.02\%$ after which it dropped steadily from the 9th day $18.63 \pm 0.02\%$ up to 18th day $17.32 \pm 0.01\%$. The unmodified (T_1) treatment recorded $5.76 \pm 0.01\%$, $7.19 \pm 0.02\%$,

$9.92 \pm 0.01\%$, $12.22 \pm 0.03\%$ $15.53 \pm 0.02\%$, $19.21 \pm 0.01\%$ and $18.61 \pm 0.02\%$ from the initial day, 3rd, 6th, 9th, 12th, 15th, and the 18th day respectively. The unmodified (T_1) treatment increasingly produced TSS from the initial day up to the maximum of 15th day and then dropped afterward up to 18th day. The modified (T_2) recorded $5.73 \pm 0.02\%$, $6.60 \pm 0.01\%$, $7.50 \pm 0.01\%$, $9.12 \pm 0.02\%$, $10.63 \pm 0.02\%$, $13.67 \pm 0.01\%$, and $17.31 \pm 0.02\%$ from the initial day, 3rd, 6th, 9th, 12th, 15th, and the 18th day respectively. The modified (T_2) mango fruits showed an increasing trend of TSS but in slower motion compared to unmodified (T_1) and modified (T_0) (Fig. 3).

The pulp TSS for the low temperature ($4 \pm 2^\circ\text{C}$) fruits, the control (L_0) recorded $5.65 \pm 0.01\%$, $7.06 \pm 0.02\%$, $9.15 \pm 0.02\%$, $14.21 \pm 0.02\%$, and $17.41 \pm 0.01\%$ from the initial day, 6th, 15th, 24th, and the 27th day respectively. The unmodified treatment (L_1) recorded $5.60 \pm 0.02\%$, $6.67 \pm 0.02\%$, $8.23 \pm 0.02\%$, $13.60 \pm 0.01\%$ and $16.24 \pm 0.01\%$ for the respective days. The modified (L_2) recorded $5.63 \pm 0.01\%$, $6.13 \pm 0.02\%$, $8.15 \pm 0.01\%$, $12.30 \pm 0.01\%$, and $14.62 \pm 0.02\%$ for the respectively as shown in (Fig. 4).

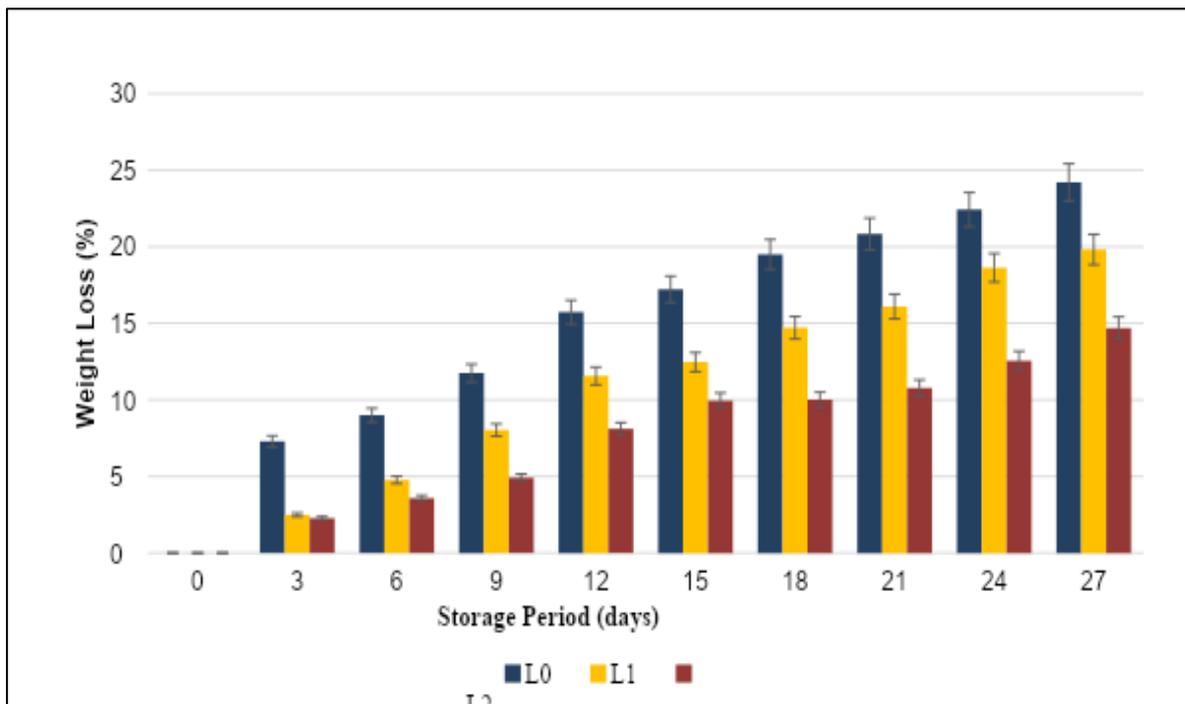


Fig. 3.2. Effect of different *M. esculenta* (CS) coating treatments on the weight loss of mango fruit during storage at low temperature ($4 \pm 2^\circ\text{C}$)

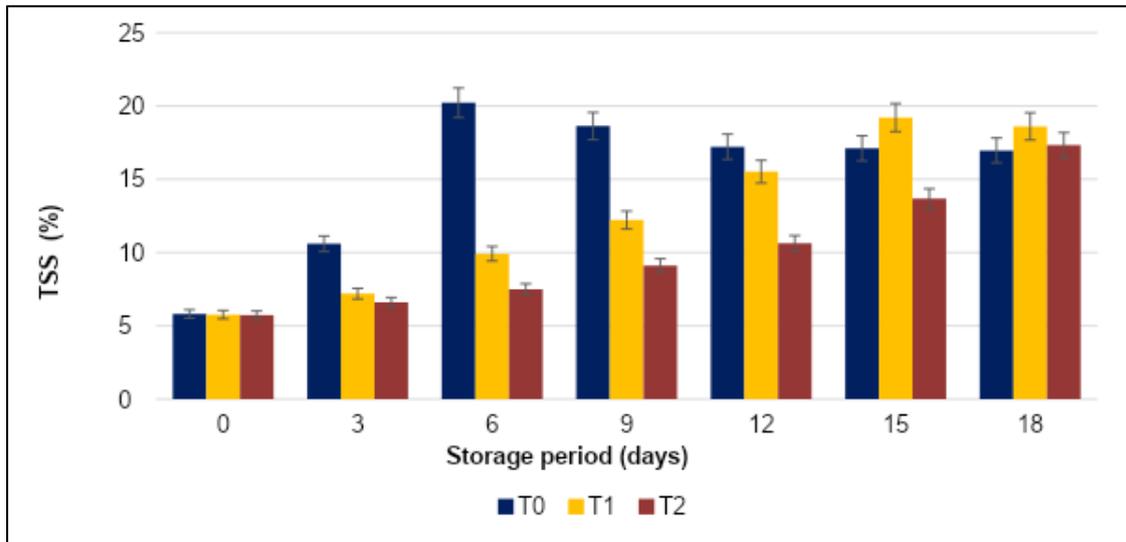


Fig. 3. Effect of different *M. esculenta* (CS) coating treatments on the pulp TSS of mangoes during storage at room temperature ($23 \pm 2^\circ\text{C}$)

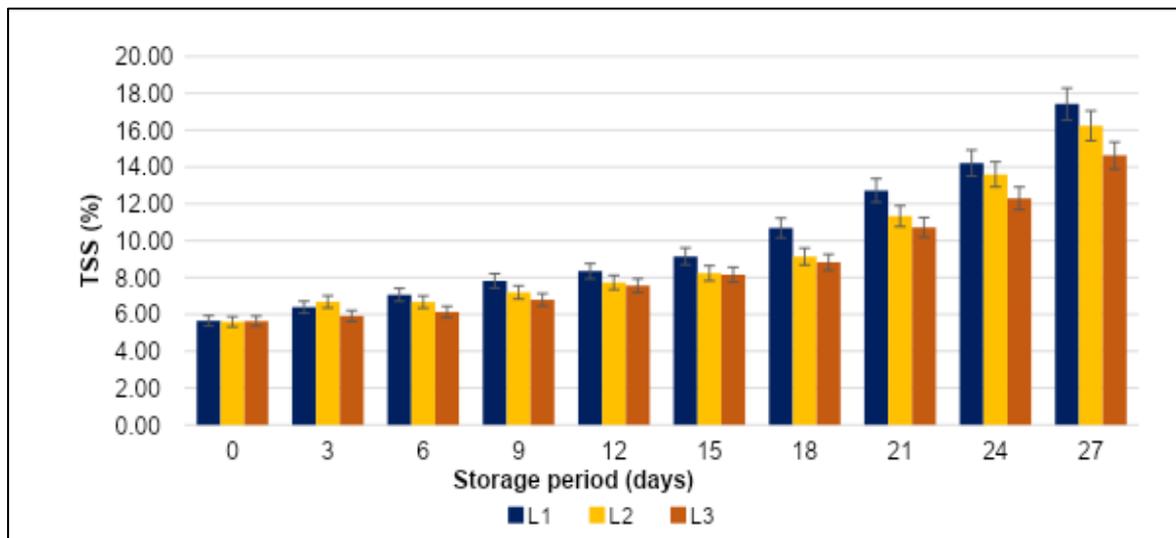


Fig. 4. Effect of different *M. esculenta* (CS) coating treatments on the pulp TSS of mangoes during storage at low temperature ($4 \pm 2^\circ\text{C}$)

The pulp TSS for the low temperature ($4 \pm 2^\circ\text{C}$) fruits, the control (L_0), unmodified (L_1), and modified (L_2) samples increased gradually but much more delayed compared ($P=0.04$) to those of room temperature conditions ($23 \pm 2^\circ\text{C}$). These findings were comparable with literature work by [28], who reported increasing pulp TSS for the control mango fruits of 5.82%, 12.13%, 20.22%, 18.75% and 17.25% from the initial day, 3rd, 6th, 9th, and the 12th respectively. The coated mango fruits indicated 5.74%, 8.74%, 13.21%, 17.72% and 20.22% for the respective days.

Total soluble solid is an important parameter which determines the sweetness of a particular fruit [29]. The increase of the pulp TSS content throughout the storage period corresponded with the progress of the ripening process, in which the highest total soluble solids content being those of control, followed by those of unmodified and modified fruit samples. The increasing trend of pulp TSS in the control could be attributed to the loss of water from the fruit and the ripening process that results in the hydrolysis of complex carbohydrates into simple sugars and glucose [30] Equation 1.



The low temperature (4 ± 2 °C) mango fruits presented a slow motion towards the increase of TSS as compared to room temperature mangoes (23 ± 2 °C), but much slower in the modified samples (L₂). The Low temperature (4 ± 2 °C) suppressed respiration rates which resulted in lower soluble solid concentration and a minimized conversion of carbohydrates to simple sugars [26]. Modified *M. esculenta* edible coating created a semi-permeable barrier around the fruit and modified the internal atmosphere by reducing oxygen and increasing carbon dioxide production [31].

3.3 Titratable Acidity (TA)

Titrate acidity of the mango pulp was significantly affected by the *M. esculenta* edible coating and the storage duration. In this study, titrate acidity of all fruit samples decreased as the storage period progressed. The decreasing trend for control (T₀) was rapid from the initial day to the 6th day, and thereafter declined steadily to the 18th day of storage. The control (T₀) fruits for the room temperature (23 ± 2 °C) condition, recorded decreasing trend of 3.53 ± 0.02 %, 0.74 ± 0.04 %, 0.47 ± 0.01 %, 0.23 ± 0.01 %, 0.18 ± 0.01 %, 0.15 ± 0.01 %, and 0.11 ± 0.01 % from the initial day, 3rd, 6th, 9th, 12th, 15th, and the 18th day respectively. The unmodified (T₁) recorded 3.64 ± 0.01 %, 1.94 ± 0.02 %, 0.82 ± 0.01 %, 0.51 ± 0.01 %, 0.40 ± 0.01 %, 0.37 ± 0.02 %, and 0.31 ± 0.02 % for the respective days. The modified (T₂) indicated a similar trend of 3.66 ± 0.02 %, 2.60 ± 0.01 %, 1.43 ± 0.01 %, 0.94 ± 0.02 %, 0.83 ± 0.02 %, 0.71 ± 0.01 %, and $0.66 \pm$

0.02% for the respectively days. The decreasing trend of the modified (T₂) fruit samples was much lower compared ($P= .01$) to unmodified (T₁) and the control (T₀) as shown in (Fig. 5).

The low temperature (4 ± 2 °C) fruits indicated abated trend which was much slower compared ($P= .03$) to that of at room temperature (23 ± 2 °C) conditions. The control (L₀) fruits recorded TA of 3.58 ± 0.01 %, 1.54 ± 0.02 %, 0.52 ± 0.01 %, 0.33 ± 0.01 %, 0.30 ± 0.01 %, and 0.23 ± 0.02 % from initial day, 6th, 15th, 18th, 24th, and the 27th day respectively. The unmodified (L₁) recorded, 3.70 ± 0.02 %, 1.63 ± 0.01 %, 0.71 ± 0.02 %, 0.54 ± 0.02 %, and 0.49 ± 0.01 % respectively days as shown in (Fig. 6). The modified (L₂) fruits recorded 3.65 ± 0.01 %, 1.79 ± 0.02 %, 1.30 ± 0.01 %, 1.18 ± 0.02 %, 1.01 ± 0.01 %, and 0.87 ± 0.02 % for the respective days. The modified (L₂) fruits retained the highest amount of TA compared to unmodified (L₁) and the control (L₀) fruits.

This result corresponded to literature survey of mango fruits by [32]. The author reported a decreasing trend of TA as 4.25%, 1.50%, 0.60%, 0.35% and 0.18% from the initial day, 3rd, 6th, 9th, and 12th day respectively for the control fruits. The fruits coated with paraffin coating recorded 4.30%, 2.45%, 1.20%, 0.80% and 0.65% for the aforementioned days respectively. Similarly, the low temperature coated fruits showed the highest amount TA at the end of storage period. They indicated TA amount of 4.42%, 2.83%, 1.60%, 1.35%, and 1.10% for the respective days.

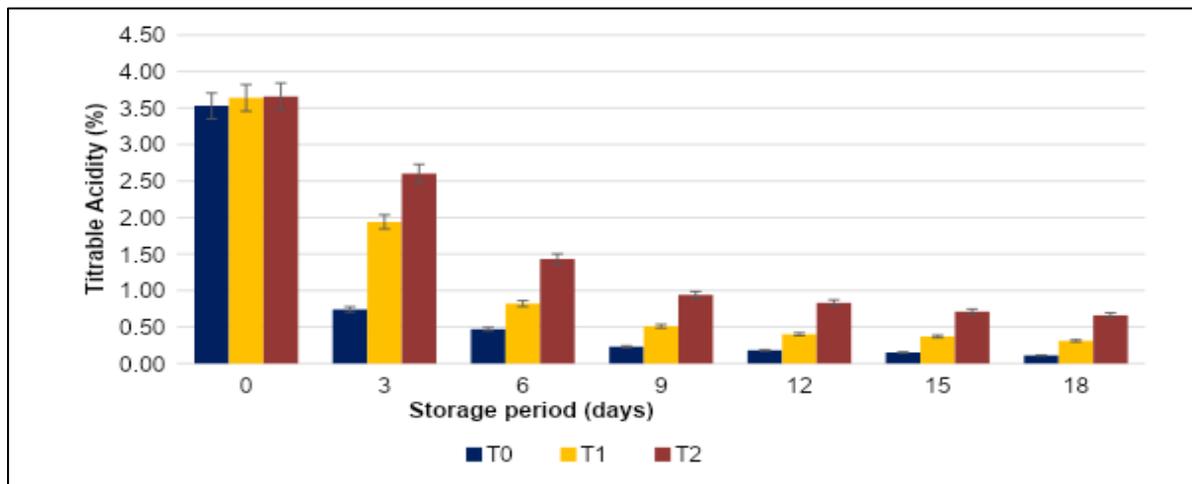


Fig. 5. Effect of different *M. esculenta* (CS) coating treatments on the pulp TA of mangoes during storage at room temperature (23 ± 2 °C)

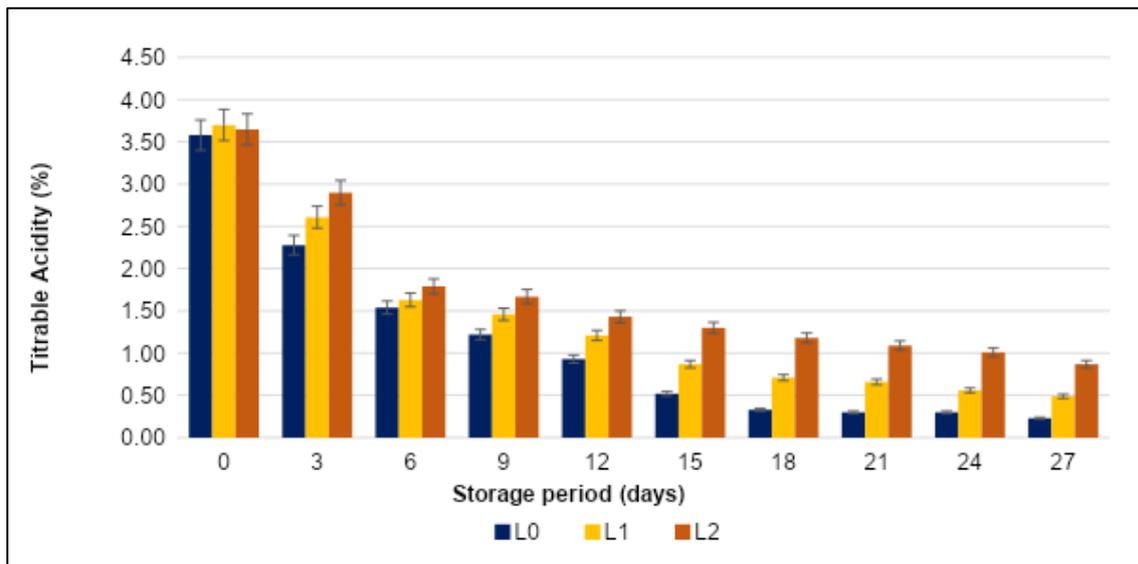


Fig. 6. Effect of different *M. esculenta* (CS) coating treatments on the pulp TA of mangoes during storage at low temperature ($4 \pm 2^\circ\text{C}$)

Titratable acidity (TA) is an important factor which determines maturity and the taste quality of the fruit [33]. The controls (T_0) and (L_0) showed a greater decline of titratable acidity and this might be attributed by increased respiration rates that resulted into disintegration of organic acids that were used up for enzymatic reactions [26]. Also, the decreased amount of TA in the control fruits could be attributed to the increase in ethylene production and respiration rate during the advent of ripening process [34]. In this study, mango fruits treated with *M. esculenta* modified coating showed higher retention of TA, which indicated that the treatment might have preserved the organic acids by inhibiting oxidation and respiration rates [35].

3.4 pH Changes

The *M. esculenta* (cassava) starch) edible coating and storage time significantly impacted the pulp pH of the mango fruits subjected to room temperature ($23 \pm 2^\circ\text{C}$) and low temperature ($4 \pm 2^\circ\text{C}$) conditions. The pulp pH of mango fruits was increased during storage period, but it was greater in the control samples (T_0 , L_0) as compared ($P = .01$) to the coated samples. The control (T_0) fruits for the room temperature ($23 \pm 2^\circ\text{C}$) condition, recorded a rapid increasing trend of 3.62 ± 0.02 , 4.63 ± 0.03 , 5.79 ± 0.01 , 6.60 ± 0.02 , 7.19 ± 0.01 , 7.51 ± 0.02 , and 8.21 ± 0.02 from the initial day, 3rd, 6th, 9th, 12th, 15th, and the 18th day of storage respectively. The unmodified (T_1) recorded a

trend of 3.61 ± 0.02 , 3.91 ± 0.01 , 4.22 ± 0.02 , 4.6 ± 0.02 , 5.39 ± 0.01 , 5.92 ± 0.01 , and 6.30 ± 0.02 for respectively days. The modified (T_2) fruit samples recorded a pulp pH of 3.64 ± 0.01 , 3.73 ± 0.03 , 3.81 ± 0.01 , 4.01 ± 0.02 , 4.40 ± 0.01 , 4.80 ± 0.01 and 5.20 ± 0.02 for the respectively days as shown in (Fig. 7).

The low temperature ($4 \pm 2^\circ\text{C}$) fruits indicated declined trend which was much slower compared ($P = .02$) to that of at room temperature ($23 \pm 2^\circ\text{C}$) condition. The control (L_0) mango fruits for low temperature ($4 \pm 2^\circ\text{C}$) condition, recorded 3.59 ± 0.02 , 3.81 ± 0.02 , 3.90 ± 0.02 , 4.08 ± 0.01 , 4.39 ± 0.02 , 4.80 ± 0.01 , 5.18 ± 0.01 , 5.39 ± 0.01 , 5.79 ± 0.01 , and 6.02 ± 0.02 from the initial day, 3rd, 6th, 9th, 12th, 15th, 18th, 21st, 24th, and the 27th day respectively. The unmodified (L_1) fruit samples recorded 3.66 ± 0.01 , 3.77 ± 0.02 , 3.87 ± 0.01 , 3.93 ± 0.02 , 4.19 ± 0.01 , 4.60 ± 0.02 , 4.81 ± 0.02 , 4.88 ± 0.01 , 5.11 ± 0.01 , and 5.21 ± 0.01 for the respectively days. The modified (L_2) samples recorded 3.62 ± 0.02 , 3.71 ± 0.02 , 3.79 ± 0.01 , 3.89 ± 0.01 , 4.09 ± 0.02 , 4.31 ± 0.02 , 4.49 ± 0.01 , 4.61 ± 0.01 , 4.79 ± 0.02 , and 4.93 ± 0.02 for the respective days as shown in (Fig. 8).

The results of this study were comparable to that of literature survey by [28]. The author reported a rapid increasing trend of pulp pH in control mango fruits as 3.70, 4.80, 5.70, 6.80, and 6.90 for a period of 12 days of storage. The coated fruits indicated a pulp pH of 3.50, 3.60, 3.80,

4.00, and 4.40 for the 12 days of storage respectively. The increasing trend for the coated mango fruits was relatively lower compared to that of the control. The increment of pH for the control samples corresponded with the decreasing amount of titratable acidity due increased rate of respiration and oxidation of organic acids such as citric acid to simple sugars over the storage time [36]. On the hand, for the treatment at low temperature ($4 \pm 2^\circ\text{C}$) samples, the pH increment was much delayed which

corresponded with the slight changes in titratable acidity. Low temperature ($4 \pm 2^\circ\text{C}$) condition suppressed the samples' reaction processes, while the *M. esculenta* coating modified the atmosphere around the treated fruits by creating a semi-permeable film that inhibited the adsorption of gases across the coat [37]. This significantly barred the development of acids leading to lower pH values in coated samples unlike the uncoated or control fruits [37].

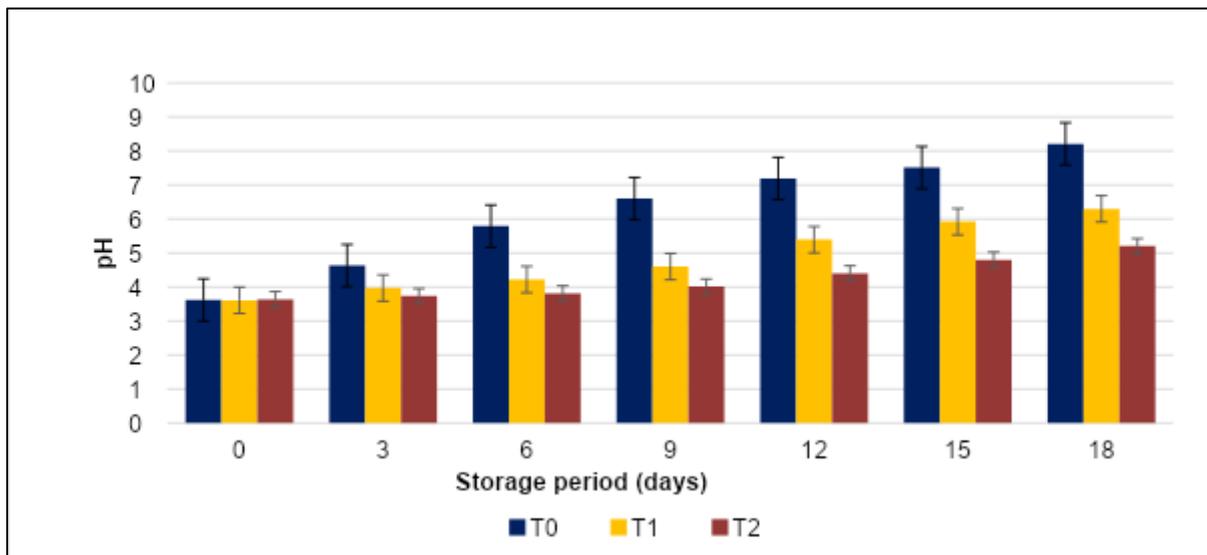


Fig. 7. Effect of different *M. esculenta* (CS) coating treatments on the pulp pH of mangoes during storage at room temperature ($23 \pm 2^\circ\text{C}$)

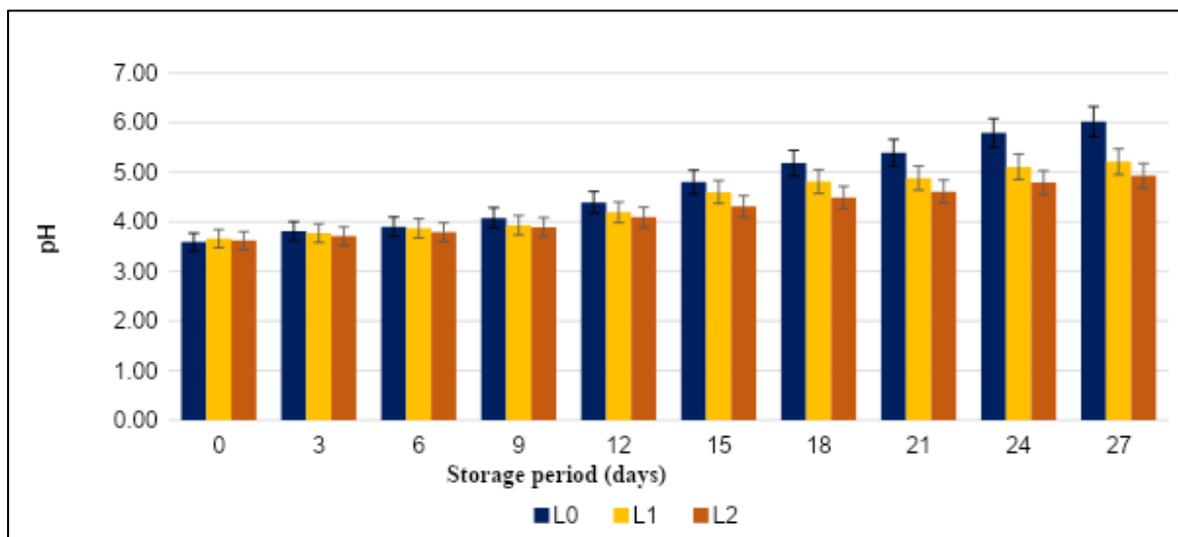


Fig. 8. Effect of different *M. esculenta* (CS) coating treatments on the pH of mangoes during storage at low temperature ($4 \pm 2^\circ\text{C}$)

3.5 Vitamin C Concentration

The amount of pulp vitamin C concentration in the mango fruits was significantly influenced by *M. esculenta* coating on the mango fruits subjected to room temperature ($23 \pm 2^\circ\text{C}$) and low temperature ($4 \pm 2^\circ\text{C}$) conditions. The amount of vitamin C concentration for the pulp of fruits decreased throughout the storage period. The control (T_0) fruits for the room temperature ($23 \pm 2^\circ\text{C}$) condition, displayed a greater decreasing ($P= .02$) amount of vitamin C concentration of 86.23 ± 0.01 mg/100g, 55.43 ± 0.02 mg/100g, 27.30 ± 0.01 mg/100g, 15.64 ± 0.02 mg/100g, 7.34 ± 0.01 mg/100g, 5.25 ± 0.01 mg/100g, and 3.74 ± 0.01 mg/100g from the initial day up to 18 days of storage at an interval evaluation of 3 days. The unmodified (T_1) fruits indicated 83.43 ± 0.02 mg/100g, 70.65 ± 0.01 mg/100g, 38.21 ± 0.01 mg/100g, 22.61 ± 0.01 mg/100g, 11.78 ± 0.02 mg/100g, 8.19 ± 0.01 mg/100g and 5.97 ± 0.01 mg/100g for the respective days. The modified (T_2) mango fruit samples indicated 85.23 ± 0.02 mg/100g, 78.73 ± 0.02 mg/100g, 49.5 ± 0.01 mg/100g, 28.41 ± 0.01 mg/100g, 16.84 ± 0.02 mg/100g, 11.63 ± 0.02 mg/100g, and 8.13 ± 0.02 mg/100g for the respective days as shown in (Fig. 9).

The low temperature ($4 \pm 2^\circ\text{C}$) fruits, initially showed a profound decreased amount of vitamin C and thereafter declined progressively ($P=.01$) as the storage period advanced (Fig. 10). The control (L_0) mango fruits for the low temperature ($4 \pm 2^\circ\text{C}$) conditions, recorded 88.13 ± 0.02 mg/100g, 78.33 ± 0.02 mg/100g, 71.49 ± 0.01 mg/100g, 59.60 ± 0.02 mg/100g, 47.30 ± 0.01 mg/100g, 35.71 ± 0.01 mg/100g, 31.30 ± 0.02 mg/100g, 12.20 ± 0.01 mg/100g, and $12.11 \pm$

0.02 mg/100g from the initial day up to 27 days of storage at an interval evaluation of 3 days. The unmodified (L_1) fruits 84.24 ± 0.02 mg/100g, 79.87 ± 0.01 mg/100g, 75.40 ± 0.01 mg/100g, 61.74 ± 0.01 mg/100g, 49.24 ± 0.01 mg/100g, 37.54 ± 0.02 mg/100g, 34.81 ± 0.01 mg/100g, 17.31 ± 0.01 mg/100g, and 14.4 ± 0.02 mg/100g for the respective days. The modified (L_2) mango fruits indicated 87.45 ± 0.01 mg/100g, 81.77 ± 0.02 mg/100g, 77.34 ± 0.01 mg/100g, 65.11 ± 0.01 mg/100g, 57.24 ± 0.01 mg/100g, 40.27 ± 0.01 mg/100g, 38.39 ± 0.01 mg/100g, 19.72 ± 0.01 mg/100g, and 17.84 ± 0.03 mg/100g for the respective days as given in (Fig. 10).

The findings of this study were comparable to that of literature work on the study of coated mangoes by [28]. The uncoated mango fruits indicated a decreasing amount of vitamin C content of 150.06 mg/100 g, 110.70 mg/100 g, 45.60 mg/100 g, 24.80 mg/100 g, and 15.60 mg/100 g for 12 days' storage at 3 days' evaluation period. The coated mangoes indicated 155.30 mg/100g, 125.80 mg/100g, 95.60 mg/100g, 58.20 mg/100g, 35.80 mg/100g for 12 days' storage. The coated mango fruits indicated lower decrease of vitamin C content as compared to the uncoated ones.

The decreasing trend in vitamin C concentration in the mango pulps at different storage intervals might be due to oxidation during respiration processes and low temperature could be possibly delayed the oxygen dependent processes. *Manihot esculenta* coating modified the atmosphere around the treated fruits by creating a semi-permeable film that delayed oxidation and respiration processes during storage period [24].

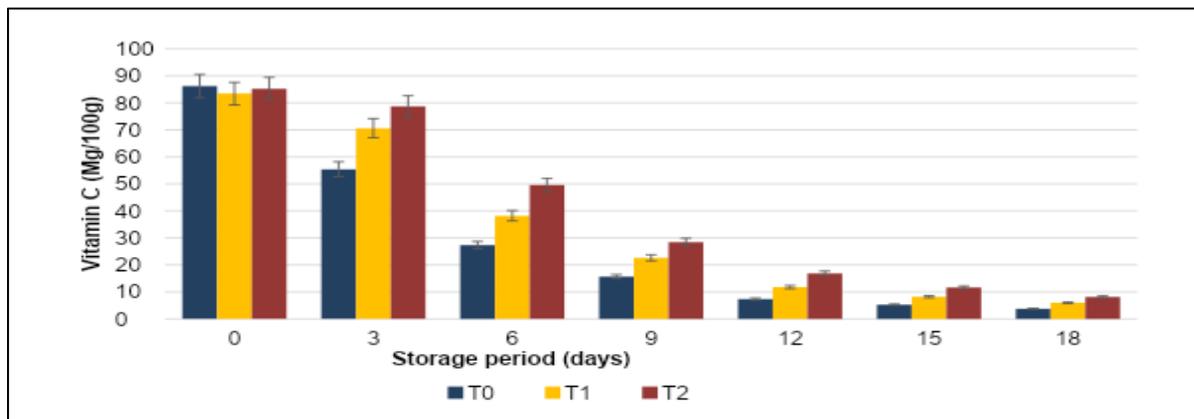


Fig. 3.9. Effect of different *M. esculenta* (CS) coating treatments on the vitamin C of mangoes during storage at room temperature ($25 \pm 2^\circ\text{C}$)

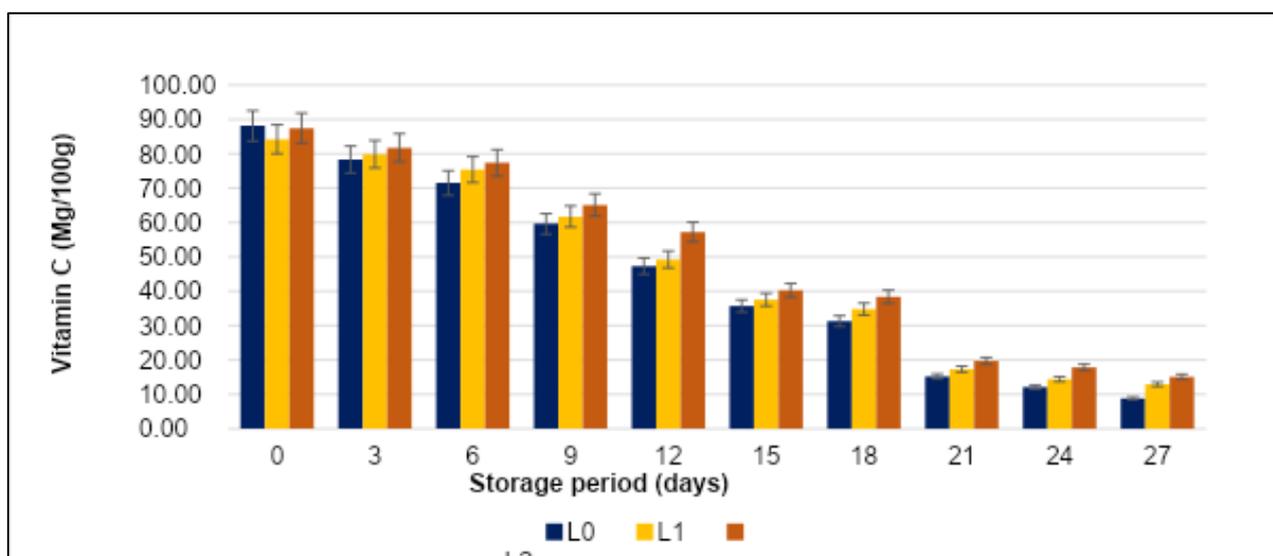


Fig. 3.10. Effect of different *M. esculenta* (CS) coating treatments on the vitamin C of mangoes during storage at low temperature ($4 \pm 2^\circ\text{C}$)

4. CONCLUSION

Results of the present study showed that *M. esculenta* edible coating incorporated with *O. gratissimum* essential oil extended the shelf life of mangoes (*Mangifera indica*) by up to 18 and 27 days of storage at room temperature ($25 \pm 2^\circ\text{C}$) and low temperature ($4 \pm 2^\circ\text{C}$), respectively. This treatment could be an effective farm-based post-harvest treatment in prolonging the shelf-life of fresh produce while maintaining their physico-chemical parameters. Equally, the physico-chemical parameters are a good indicator of the shelf-life of the mango fruit and hence fruits since with coated fruits the variations are profound in respect to the optimized conditions.

ACKNOWLEDGEMENTS

The authors are grateful to the World Bank and the Inter-University Council of East Africa for the fellowship awarded to Decrah M. Nyangena through the Africa Centre of Excellence in Phytochemicals, Textile and Renewable Energy (ACE II PTRE) at Moi University, Kenya which made this work possible.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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