Sahel Journal of Life Sciences FUDMA 3(2): 491-505, 2025

Sahel Journal of Life Sciences FUDMA (SAJOLS)
June 2025 Vol. 3(2): 491-505
ISSN: 3027-0456 (Print)
ISSN: 1595-5915 (Online)
DOI: *https://doi.org/10.33003/sajols-2025-0302-56*

Research Article

Effect of Bitter Leaf Extract on Post-harvest Shelf life and Quality of Mango Fruits During Storage

***Promise Adaku Nwanganga[1], Samuel Peter Malu[2], Peter Agorye Adie[3], Comfort Onyeche Ochida[1] and Love Amauche Egbegbedia[1]**

[1]Centre for Food Technology and Research, Benue State University, Makurdi, Benue State, Nigeria
[2]Department of Industrial Chemistry, Federal University Wukari, Taraba State, Nigeria
[3]Department of Biological Sciences, Benue State University, Makurdi, Benue State, Nigeria
****Corresponding Author's email*: promiseugola@gmail.com; Phone: +2348064186348**

ABSTRACT
The study aimed to evaluate the effect of bitter leaf on the shelf-life of mango fruits during storage. Healthy mango fruits of two varieties, *Brokin* and *Julie,* obtained from the fruit market in Makurdi were treated by dipping them in bitter leaf extract and stored at room temperature. The fruits were analyzed for physicochemical properties, and fungi and other organisms causing decay in mango fruits during storage were isolated, identified, and tested for pathogenicity. Data obtained from the physicochemical and microbial properties of postharvest mangoes were recorded and statistically analyzed to compare the mean values using the post hoc Fisher's Least Significant Difference (FLSD) multiple range test. The experiment was laid out in a completely randomized design (CRD) with three replications. Significant variations were observed among the varieties in relation to most of the parameters studied. The physiochemical properties showed that the beta-carotene content, total soluble content, pH, weight loss, postharvest decay, marketability, shelf life of mango fruits increased from 2.50 to 75.07, 0.00 to 11.69, 3.40 to 7.92, 0.00 to 100.00, 0.46 to 7.12, 1.00 to 7.80, 1-25 days respectively while firmness, titratable acidity and vitamin C decreased from 5.21 to 2.72, 1.29 to 0.10, 3.35 to 0.54 respectively. Three fungi namely *Aspergillus niger, Botryodiplodia theobromae*, *Colletotrichum gloeosporioides* were isolated from the decaying mango fruits. The findings therefore indicate that extract from the leaf of bitter plant can be used to extend the shelf life and quality of mango fruits.

Keywords: Bitter Leaf; Mango Fruits; Postharvest; Quality; Shelf Life

Citation: Nwanganga, P.A., Malu, S.P., Adie, P.A., Ochida, C.O., & Egbegbedia, L.A. (2025). Effect of Bitter Leaf Extract on Post-harvest Shelf life and Quality of Mango Fruits During Storage. *Sahel Journal of Life Sciences FUDMA*, 3(2): 491-505. DOI: *https://doi.org/10.33003/sajols-2025-0302-56*

INTRODUCTION

Mango (*Mangifera indica L.*) is a tropical and subtropical fruit belonging to the *Anacardiaceae* family, is usually consumed for its pleasant taste and aroma (Shah *et al.,* 2010; Ntsoane et al., 2020). It is rich in pectin, vitamin C, and provitamin A (β-carotene), which contribute significantly to reducing blood cholesterol levels and strengthening the immune system (Lebaka *et al.,* 2021). These inherent nutritional and sensory attributes have made mango fruits highly sought after in the global market. With evolving consumer preferences and increased awareness among producers, the export of mangoes is expanding internationally. Among numerous tropical fruits mango fruits play a noteworthy role as a horticultural commodity. Based on the records of the Food and Agriculture Organization, in 2019, mango accounts for almost quarter of total tropical fruit exports, whereas, the demand shows a gradual increment over the past ten years (FAO, 2020).

The mango fruits is one of the most economically important tropical fruits globally, prized for its rich nutritional content, diverse varieties, and extensive uses in food, cosmetics, and pharmaceuticals. Internationally, the demand for mango fruits has surged due to growing consumer preference for healthy and exotic fruits, fueling global trade and boosting export revenues, especially in tropical regions. In Nigeria, mango holds significant economic potential as one of the country's most widely cultivated and consumed fruits, contributing to rural livelihoods, employment, and food security. Despite its underexploited export potential, Nigeria ranks among the top mango producing countries, with opportunities to improve quality and market access for international trade (FAO, 2021). Enhancing value chains and post-harvest handling practices could elevate Nigeria's position in the global mango market, thereby increasing foreign exchange earnings and supporting agricultural development.

However, mango is a highly perishable fruit, requiring processing to ensure year-round availability in various forms (FAOSTAT, 2012). Developing new mango based products can enhance its market value. Mangoes are commonly processed into juice, nectar, fruit leather, puddings, chutneys, jams, beverages, pickles, fruit particulates, and frozen pulp. They are also used as flavor enhancers in baked goods, ice creams, yogurts, and even as dried pieces in salads or fruit cocktails (Crane *et al.,* 2006). Notable export varieties include Kent, Haden, Tommy Atkins, and Keitt (Sauco, 2004). Although Nigeria ranks 9th among the world's top mango producing countries, it is absent from the list of leading exporters (FAOSTAT, 2007). Major mango producing states in Nigeria include Benue, Jigawa, Plateau, Yobe, Kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa, Taraba, and the FCT. Despite substantial production, the country faces significant post-harvest losses estimated at 25.51% due to issues arising during transport, storage, and market handling (Ali *et al.,* 2019). Mango fruits undergo several physiological and biochemical transformations during ripening, primarily driven by ethylene production and increase in respiration rates (Kharwade *et al.,* 2022). As a climacteric fruit, mangoes ripen rapidly and have a limited shelf life, necessitating careful postharvest handling to reduce spoilage. Maintaining storage temperatures 10–15 °C lower than ambient and relative humidity around 90% can significantly help in preserving fruit quality (Yahia, 2011). Additionally, coating each fruit with a plant based film that acts as a semi-permeable barrier helps regulate gas exchange (CO_2 and O_2), thereby reducing metabolic activity and water loss (Umesh *et al.,* 2017).The objective of this research is to evaluate the effect of bitter leaf extract as coatings /films on the changes in physicochemical parameters related to mango quality during storage and its role in extending the shelf life of the fruits.

MATERIALS AND METHODS

Reagents

All the reagents used in the study were of analytical grade and produced by British Drug House (BDH) Poole England and Sigma Aldrich Chemical Co. Inc. U.S.A.

Experimental Design/ layout

Factors in the experiment

i. Varieties of mango fruits (*Brokin* and *Julie*)
ii. 1 plant leaf extracts including control

Experimental design 2 x 2 factorial in Complete Randomized Design

Treatment combinations = 2 x 2 = 4 treatments

Replications = 3

Total plots therefore = 3 x 4 = 12.

Each plot contained 8 mango fruits = 8 x 12 = 96 fruit samples.

Finally, the extracts solutions were filtered before use and stored in refrigerator at 5°C (Liamngee *et al.,* 2015).

Sample collection and Preparation

Mango fruits used for this study were obtained from the fruit market, Makurdi, Benue State. Fresh leaves of bitter leaf (*Vernonia amygdalina*) were obtained from the campus of the Benue State University, Makurdi. The varieties bought include *Brokin* and *Julie*. They were identified and authenticated at the Herbarium of the Department of Biological Sciences, Benue State University, Makurdi, Nigeria.

Sample Preparation

Fresh bitter leaves were washed and air dried in a dust-free room for 10 days. It was then grounded into powder using a Philips HR2221/00 blender (700W, 5-speed). The powder was then sieved through a sieve of 1mm to obtain the fine powders. Then 3% extract was prepared by dissolving 30 g of the powdered plant in 1000 mL of distilled water and soaked for 24 hours. Thereafter, the extract was filtered with a muslin cloth into clean plastic container to obtain the solution. The extract was stored in well covered clean jars and kept away from direct light at room temperature. Ripe, firm, smooth and healthy mango fruits of two varieties were selected and washed with clean water to remove dirt, rinsed again in water and kept to shade dry before treatment. The two varieties of the mango fruits (*Brokin* and *Julie)* were treated by dipping them in the concentration of the bitter leaf extracts. The fruits were removed and arranged on wooden racks in plastic crates and kept at room temperature. *Brokin* and *Julie* were used for each treatment; each replicated three times and arranged in complete randomized design with each plot containing thirty fruits. Untreated mango fruits were used as control.

Postharvest decay percentage (PDP)

Postharvest decay or rotting was determined by visual evaluation for symptoms of decay during the storage period. The percent decay loss was calculated by using the formula reported by Singh et al. (2018). Samples having symptoms of decay were counted, recorded and expressed in percentage as shown below. Samples having symptoms of decay were counted, recorded and expressed in percentage as shown below.

$$\text{PDP} = \frac{\text{Number of fruits decaying}}{\text{Total number of fruits}} \times 100$$

Weight loss percentage (g)

Mango fruits were weighed at the beginning and during the storage intervals using weighing balance. The difference between the initial and final weight of the fruits was considered as total weight loss during the storage interval and expressed as a percentage by (Kumar *et al.,* 2021)

$$\text{WLP} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

Total soluble solids (TSS) (° Brix)

The TSS content of the mango fruits was determined using a hand-held refractometer (Model 5543 P5995, USA). A homogenous sample was prepared by blending the mango flesh in a Philips HR2221/00 blender (700W, 5-speed) for one minute. Two drops of the mango fruit sample were carefully applied on the refractometer using a plastic dropper and the reading was obtained directly as percentage soluble solids concentration in ° brix (Ranganna, 2014).

Titratable acid (TA) (%)

Titratable acidity was determined as per method reported by Ranganna (2014). The Mango flesh was chopped into small portion and blended in a Philips HR2221/00 blender (700W, 5-speed). Exactly 10 mL of the juice were filtered using a funnel with filter paper in a beaker. Exactly 5 mL of the filtrate was pipetted into a conical flask then 10 mL of sterile distilled water was added to make the fruit colour light to facilitate clear endpoint detection. Thereafter, two drops of phenolphthalein indicator were added. 0.1 N NaOH was added dropwise and the solution shaken thoroughly until a pink colour was obtained. The acid content of the mango sample was calculated using the formula below:

$$\%\ \text{T.A.} = \frac{\text{V} \times \text{M} \times \text{F}}{\text{Volume of mango juice}} \times 100$$

Where V = volume of 0.1N NaOH used, M = molarity of NaOH and F = factor of citric acid (0.0064).

Shelf life

Shelf life of mango fruits was evaluated by counting the number of days the mango fruits were acceptable for marketing and consumption. It was decided based on appearance and spoilage of the mango fruits (Kumar *et al.,* 2021).

Firmness (N/cm)

Firmness was measured as the maximum penetration force (N) reached during tissue breakage using a standard probe. The registered force at the penetration of a standard probe up to a certain depth (cm) was read as firmness. The firmness of the fruits was determined using a penetrometer (Model 327) (Tigist *et al.,* 2013).

Vitamin C/Ascorbic acid content

The ascorbic acid content was estimated by the procedure given by Ranganna (2014). Exactly 100 mL solution was prepared by dissolving 100 mg of L - ascorbic acid in 3% metaphosphoric acid. The 10 mL was then diluted with 100 mL of 3% metaphosphoric acid (1 mL = 0.1 mg ascorbic acid). Exactly 5 mL of standard ascorbic acid were used to standardize the dye, using pink as the end point. 10 - 20 mL of pulp were treated in 100 mL of 3% metaphosphoric acid and filtered. In a conical flask, 10 mL of pulp were titrated against 2, 6-dichloroindophenol dye. The arrival of pink hue was the tipping moment. The ascorbic acid content was estimated using the formula below.

Ascorbic acid (mg/100 g)

$$= \frac{\text{Titer} \times \text{Volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Vol of sample}}$$

$$\text{Dye factor} = \frac{0.5}{\text{Titer vaule of standard ascorbic acid}}$$

pH

Mango fruit flesh was chopped into small pieces and grounded into a fine paste by an electric blender for one minute. Exactly 10 mL of the mango juice was transferred into a beaker and the pH of the paste was determined by inserting the pH meter into the paste and taking the readings (Ranganna, 2014).

Marketability

Marketable quality was evaluated according to the scoring method used by (Mohammed et al., 1999) with slight modification based on a 1 – 9 rating scale. Thus; 1 **–** 2.49 = unsalable, 2.5 - 4.49 = saleable, 4.5 - 6.49 = Good, 6.5 - 8.49 = Very good, 8.5 – 9.00 = Excellent. Evaluation of the overall market acceptability of the fruit was done by a panel of nine people based on colour, firmness, surface defects, and signs of decay as visual parameter.

Beta - carotene (mg/100 g)

The Mango fruit flesh was chopped into small pieces and grounded into a fine paste by an electric blender for one minute. Exactly 10 mL of the juice were transferred into a beaker after which 10mL of petroleum ether was added and the solution was vigorously shaken for 1 minute. The solution was filtered through Whatman filter paper and the filtrate will be taken for spectrophotometric determination. Sample absorbance was measured at 451 nm and beta-carotene was calculated using the formula as reported by (Ibitoye, 2005).

ß-carotene = A451 x 19.96 (mg / 100 g), where: A451 - absorbance at 451 nm, 19.96 - extinction coefficient.

Temperature

The temperature and relative humidity in the storage room were evaluated throughout the storage period using a Brannan wet and dry bulb thermometer (Model: 13/471/2). The thermometer was placed in the storage room and readings were recorded for temperature in the mornings, afternoons and evenings (Jahun *et al.,* 2016).

Media preparation

The medium used for isolation of fungi was Potato Dextrose Agar (PDA) which was prepared according to the manufacturer's instruction.

Isolation of fungi

Small portion were cut from mango fruits infected with rot and surface sterilized by dipping in 1% sodium hypochlorite (NaOCl) solution for one minute. They were removed and rinsed in several changes of sterile distilled water then placed on sterile paper towels to dry. They mango fruit sample were then placed on solidified Potato Dextrose Agar medium. Three replicates were made for each sample. The inoculated plates were incubated at ambient temperature and observations were made for microbial growth. After 5 - 7 days of growth, sub culturing was done to obtain pure cultures of the isolates as reported by Ogo-Oluwa and Liamngee (2016).

Identification of fungi

Identification was done microscopically and macroscopically. Colony characteristics such as appearance, change in medium colour and growth rate were observed. Shape of the conidia and conidiophores were taken note of. These features were matched with standards described by Barnett and Barry (1999) as reported by Ogo-Oluwa and Liamngee (2016).

Pathogenicity test

Mycelia plug of the fungal isolates from 5-day old cultures were used to inoculate six mango fruits per pathogen. On appearance of symptoms, the tissues at the margin of the healthy and diseased parts were excised, sterilized and placed onto Potato Dextrose Agar (PDA) and incubated at ambient temperature for 5 – 7 days. At the end of this period, morphological characteristics and growth patterns observed in each case were compared with the ones of the original isolates. Four mango fruit each was used for each fungal isolate replicated four times and arranged in completely randomized design. Controls were mango fruits inoculated with sterile PDA only as reported by Ogo-Oluwa and Liamngee (2016).

Data Analysis

Data collected were analyzed using SPSS version 21 for multiple factor analysis of variance (ANOVA) and correlation analyses. The data was reported as the mean value ± standard deviation of triplicates. The post hoc Fishers least significant difference (FLSD) multiple range test was used in multiple comparisons to assess significant difference in the data with confidence level of p≤ 0.

RESULTS AND DISCUSSION

Beta-carotene content of the mango fruits during storage

The mean effect of both mango variety and botanical factors on beta-carotene content during storage was statistically significant (P ≤ 0.05), as shown in Table 1. The *Brokin* variety exhibited higher beta-carotene content, ranging from 2.53±0.02 to 63.18±0.29, compared to the *Julie* variety, which ranged from 3.51±0.01 to 50.12±0.39. Storage duration had a clear influence on beta-carotene levels in the mango fruits. Among the varieties, *Brokin* showed significantly higher beta-carotene levels on days 17 and 25 of storage. The lowest beta-carotene content was found in the untreated (control) fruits of both *Brokin* and *Julie* varieties, with values ranging from 2.50±0.01 to 45.85±3.79, and these were significantly lower than beta-carotene content found in treated fruits. The influence of storage time on beta-carotene content observed in this study is in contrasts with findings by Tigist & Wosene (2015), who reported higher carotene levels in untreated fruits and lower levels in treated ones, but in agreement with the findings of Liamngee *et al. (*2018), who reported that higher carotene content in treated fruits. These differences could be attributed to variations in carotenoid composition, which can differ greatly depending on fruit or vegetable type and variety (Kimura and Rodriguez-Amaya, 2004). A key characteristic of fruit ripening is the sharp increase in carotenoid content. Based on the current findings, temperature also plays a significant role in chlorophyll degradation and carotenoid formation. At lower temperatures, chlorophyll breakdown occurs more slowly, which delays the ripening process and results in slower and reduced carotene synthesis.

Firmness of mango fruits during storage

The firmness of the mango fruits was not statistically significant (P ≥ 0.05) throughout the observation period, as shown in Table 2. Among the mango fruits samples, the *Brokin* variety treated with bitter leaf extract recorded the highest firmness values, ranging from 5.15±0.02 to 4.35±0.01. This was higher than the firmness of the *Juli*e variety, which ranged from 5.11±0.05 to 3.95±0.01, and both were significantly firmer than the untreated control fruits, which ranged from 5.08±0.02 to 2.97±0.05. The lowest firmness levels were observed in the untreated (control) mango fruits of both the *Brokin* and *Julie* varieties, and these were significantly lower than those of the treated fruits. Most notably, the control mango fruits experienced a greater loss in firmness during storage. This reduction in firmness is likely due to increased metabolic activity and the action of cell wall-degrading enzymes, which weaken the fruit skin and increase cell permeability, resulting in greater moisture loss (Zakki *et al.,* 2017).

Total Soluble Solids (TSS) of mango fruits during storage

The total soluble solids (TSS) content of the mango fruits was statistically significant (P ≤ 0.05) throughout the study period, as presented in Table 3. Among the treatments, the *Julie* variety treated with bitter leaf extract showed the highest TSS values, ranging from 0.58±0.02 to 11.69±0.10, compared to the *Brokin* variety, which ranged from 0.58±0.00 to 11.44±0.05. These values were significantly greater than those recorded in the control fruits (untreated). The control fruits of both *Brokin* and *Julie* varieties recorded the lowest TSS levels, which were notably lower than those of the treated fruits. Table 3 also indicates a consistent increase in TSS from the start to the end of the storage period for both treated and untreated (control) mango fruits. This rise in TSS during ripening is likely due to increased enzymatic activity that converts starch into soluble sugars (Zhong *et al.,* 2006). These findings align with those of Baloch & Bibi (2012), who reported that TSS levels rise with fruit ripening, especially at higher storage temperatures.

Table 1: Beta-carotene content of the mango fruits during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	2.53^{a}±0.02	4.49^{a}±0.03	26.85^{a}±0.05	45.15^{a}±0.13	75.07^{a}±0.06	92.43^{a}±0.68	70.45^{a}±0.56	63.18^{a}±0.29
	Control	2.50^{b}±0.01	3.18^{b}±0.03	6.75^{b} ±0.06	13.81^{b}±0.18	29.44^{b}±3.76	49.41^{b}±2.33	54.56^{b}±5.76	45.85^{b}±3.79
	Mean	2.51±0.01	3.83±0.03	16.80±0.06	29.48±0.15	52.25±0.91	70.92±1.50	62.50±3.16	54.51±2.04
	CV%	18.60%	15.13%	41.87%	38.14%	31.77%	22.88%	11.38%	13.24%
Julie	Bitter leaf	3.51^{a}±0.01	6.09^{a}±0.08	25.89^{a}±0.01	39.50^{a}±0.43	58.11^{a}±0.04	71.33^{a}±0.67	45.47^{a}±0.42	50.12^{a}±0.39
	Control	2.50^{b}±0.01	2.95^{b}±0.05	7.40^{b} ±0.53	12.68^{b}±0.46	25.98^{b}±2.29	44.86^{b}±1.87	24.82^{b}±0.24	39.80^{b}±0.52
	Mean	3.00±0.01	4.52±0.07	16.64±0.27	26.09±0.44	42.04±0.17	58.09±1.27	35.14±0.33	44.96±0.45
	CV%	0.33%	1.54%	1.62%	1.68%	0.40%	2.18%	0.93%	1.00%

Values represent means of triplicate values ± sð (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Table 2: Firmness of mango fruits during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	5.15^{a}±0.02	5.12^{a}±0.02	5.10^{a}±0.02	4.96^{a}±0.01	4.73^{a}±0.01	4.73^{a}±0.01	4.54^{a}±0.01	4.35^{a}±0.01
	Control	5.08^{b}±0.02	4.96^{b}±0.01	4.53^{b}±0.01	4.08^{b}±0.03	3.95^{b}±0.01	3.95^{b}±0.01	3.56^{b}±0.05	2.97^{b}±0.05
	Mean	5.10±0.02	5.01±0.01	4.81±0.02	4.52±0.02	4.34±0.01	4.34±0.01	4.05±0.03	3.66±0.03
Julie	Bitter leaf	5.11^{b}±0.05	4.93^{a}±0.01	4.78^{a}±0.01	4.51^{a}±0.01	4.57^{a}±0.01	4.48^{a}±0.01	4.25^{a}±0.01	3.95^{a}±0.01
	Control	5.21^{b}±0.01	5.10^{b}±0.05	4.50^{b}±0.01	4.22^{b}±0.19	4.27^{b}±0.10	4.27^{b}±0.01	3.82^{b}±0.03	2.72^{b}±0.37
	Mean	5.16±0.03	5.01±0.03	4.64±0.01	4.39±0.10	4.42±0.05	4.37±0.01	4.03±0.02	3.11±0.19
	CV%	0.58%	0.59%	0.21%	2.27%	1.13%	0.22%	0.49%	6.10%

Values represent means of triplicate values ± sð (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Table 3: Total Soluble Solids (TSS) of mango fruits during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	0.58^{b}±0.00	6.79^{a}±0.21	10.68^{a}±0.10	10.45^{a}±0.39	10.78^{a}±0.10	9.68^{a}±0.16	10.51^{a}±0.19	11.44^{a}±0.05
	Control	0.97^{a}±0.06	2.53^{b} ±0.11	7.25^{b}±0.25	8.68^{b}±0.46	4.70^{b}±0.40	7.63^{b}±0.15	8.22^{b}±0.13	9.47^{b}±0.46
	Mean	0.77±0.03	4.66±0.16	8.96±0.17	9.56±0.42	7.74±0.25	8.65±0.15	9.36±0.16	10.45±0.25
	CV%	3.89%	3.43%	1.95%	4.44%	3.22%	1.79%	1.70%	2.44%
Julie	Bitter leaf	0.58^{b}±0.02	8.09^{a} ±0.50	11.68^{a}±0.10	5.79^{a} ±0.18	10.78^{a}±0.10	9.93^{a}±0.13	10.37^{a}±0.29	11.69^{a}±0.10
	Control	0.77^{a}±0.21	6.20^{b}±0.17	8.47^{b}±0.47	4.01^{b}±0.23	11.45^{b}±0.33	9.88^{b}±0.54	8.80^{b}±0.26	10.20^{b}±0.26
	Mean	3.63±0.12	7.14±0.33	10.07±0.28	4.90±0.20	11.11±0.1	9.90±0.32	9.58±0.28	10.94±0.18
	CV%	3.30%	4.62%	28.50%	4.08%	1.93%	3.23%	2.87%	1.64%

Values represent means of triplicate values ± sð (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Titratable acidity (TA) of mango fruits during storage

The titratable acidity (TA) of the mango fruits was not statistically significant ($P \geq 0.05$) throughout the observation period, as shown in Table 4. Among the varieties of the mango fruit, the *Brokin* variety treated with bitter leaf extract exhibited the highest titratable acidity content (ranging from 0.58±0.02 to 10.37±0.29), surpassing the *Julie* variety within the same range, except on days 1 and 21. This acidity level was significantly greater than that of the untreated (control) fruits. Conversely, the lowest TA values were recorded in the control fruits of both the *Brokin* and *Julie* varieties, with values ranging from 1.02±0.01 to 0.19±0.09 and from 1.03±0.02 to 0.21±0.03, respectively. These were significantly lower than the values found in treated fruits. Table 4 also indicates a general decline in fruit firmness across both treated and untreated mango fruits during storage. The TA content in both coated and untreated fruits decreased over time; however, treated fruits maintained significantly higher acidity content ($P < 0.05$) compared to the controls. This supports findings by Yaman & Bayoindirli (2002), which suggest that edible coatings slow down acid metabolism. As organic acids like malic and citric acids serve as primary substrates in fruit respiration, their reduction is anticipated due to increased cellular respiration during storage (El-Anany *et al.,* 2009).

Vitamin C /ascorbic content of mango fruit during storage

The vitamin C content of the mango fruits was statistically significant ($P \leq 0.05$) throughout the observation period, as shown in Table 5. Among the varieties of the mango fruit, the *Julie* variety treated with bitter leaf extract exhibited the highest vitamin C content, ranging from 0.78±0.02 to 1.56±0.89, compared to the *Brokin* variety, which ranged from 0.77±0.02 to 1.52±0.04. These values were significantly higher than those recorded for the untreated control fruits. In contrast, the lowest vitamin C content was found in the control fruits of both *Brokin* and *Julie* varieties, with values ranging from 0.76±0.03 to 0.82±0.02 and 0.82±0.08 to 0.50±0.36, respectively, which were significantly lower than those of the treated samples. Furthermore, there was an initial increase in ascorbic acid content at the start of the study, followed by a decline toward the end of the storage period. These results align with the findings of Tigist et al. (2011), who also observed a rise in ascorbic acid content followed by a decrease at the end of storage. Similarly, Ali et al. (2010) reported a reduction in the rate of ascorbic acid degradation in gum Arabic-coated tomatoes during ripening.

pH of mango fruits during storage

The pH had a significant difference ($P \leq 0.05$) on the mango fruits throughout the observation period, as shown in Table 6. The control mango fruits exhibited the highest pH values compared to those of the *Brokin* and *Julie* varieties. The *Brokin* variety recorded the lowest pH values, ranging from 3.47±0.06 to 7.22±0.01, which were significantly lower than those of the *Julie* variety (3.47±0.01 to 7.40±0.01). According to the data in Table 5, there was a consistent upward trend in pH levels in both treated and untreated fruits during storage. This steady increase in pH across all treatments could be attributed to the breakdown of organic acids used as substrates during respiration. These findings align with those of Wani et al. (2014), who reported that as ripening progresses or storage duration increases, total acidity tends to decline, leading to a rise in fruit pH.

Table 4: Titratable acidity (TA) of mango fruits during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	1.02^{a}±0.01	1.26^{a}±0.02	1.10^{a}±0.01	1.01^{a}±0.03	0.83^{a}±0.06	0.57^{a}±0.02	0.32^{a}±0.04	0.27^{a}±0.04
	Control	1.02^{a}±0.01	0.97^{b}±0.01	0.78^{b}±0.01	0.57^{b}±0.03	0.39^{b}±0.17	0.19^{b}±0.09	0.10^{b}±0.02	0.19^{b}±0.09
	Mean	1.02±0.01	1.11±0.015	0.94±0.01	0.79±0.03	0.61±0.11	0.66±0.05	0.21±0.04	0.23±0.06
	CV%	0.98%	1.35 %	1.06%	3.79%	18.85%	8.33%	19.04%	28.26%
Julie	Bitter leaf	1.04^{a}±0.03	1.29^{a}±0.02	1.09^{a}±0.04	0.93^{a}±0.02	0.81^{a}±0.04	0.47^{a}±0.03	0.34^{a}±0.03	0.28^{a}±0.03
	Control	1.03^{b}±0.02	0.99^{b}±0.03	0.86^{b}±0.12	0.72^{b}±0.09	0.44^{b}±0.05	0.21^{b}±0.03	0.12^{b}±0.01	0.21^{b}±0.03
	Mean	1.55±0.02	1.14±0.02	0.97±0.08	0.82±0.05	0.62±0.04	0.34±0.03	0.23±0.02	0.24±0.03
	CV%	1.61%	1.75%	8.24%	6.70%	7.25%	8.82%	8.69%	12.50%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Table 5: Vitamin C /ascorbic evaluation of mango fruit during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	0.77^{a}±0.02	0.54^{a}±0.01	0.7^{a}±0.02	1.16^{a}±0.10	2.58^{a}±0.10	3.35^{a}±0.04	2.89^{a}±0.03	1.52^{a}±0.04
	Control	0.76^{b}±0.03	0.92^{b}±0.03	1.54^{b}±0.12	2.75^{b}±0.04	3.15^{b}±0.04	2.03^{b}±0.02	1.10^{b}±0.17	0.82^{b}±0.02
	Mean	0.76±0.02	0.73±0.02	1.12±0.07	1.94±0.07	2.86±0.07	5.38±0.03	2.00±0.11	1.17±0.03
	CV%	3.28%	2.73%	6.25%	3.60%	2.44%	0.55%	0.05%	2.56%
Julie	Bitter leaf	0.78^{a}±0.02	0.54^{a}±0.03	0.69^{a}±0.05	1.26^{a}±0.04	2.71^{a}±0.20	3.16^{a}±0.03	2.27^{a}±0.06	1.56^{a}±0.89
	Control	0.82^{a}±0.08	0.76^{b}±0.05	2.35^{b}±0.07	2.55^{b}±0.02	3.08^{b}±0.02	1.83^{b}±0.02	0.96^{b}±0.04	0.50^{b}±0.36
	Mean	0.80±0.05	0.65±0.04	1.52±0.06	1.90±0.03	2.89±0.11	2.49±0.02	1.61±0.05	1.03±0.62
	CV%	0.06%	6.15%	3.94%	1.57%	3.80%	1.00%	3.10%	60.19%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Table 6: pH of mango fruits during storage

Variety	Botanical	Day 0	Day1	Day5	Day9	Day13	Day17	Day21	Day25
Brokin	Bitter leaf	3.47^{b}±0.06	3.56^{b}±0.01	4.21^{b}±0.01	4.32^{b}±0.01	5.11^{b}±0.02	5.32^{b}±0.01	6.51^{b}±0.01	7.22^{b}±0.01
	Control	3.84^{a}±0.03	4.97^{a}±0.01	4.57^{a}±0.01	4.75^{a}±0.01	5.61^{a}±0.01	6.90^{a}±0.15	7.22^{a}±0.01	7.82^{a}±0.01
	Mean	3.65±0.04	4.26±0.01	4.39±0.01	4.49±0.01	5.36±0.02	6.11±0.08	6.86±0.01	7.52±0.23
Julie	Bitter leaf	3.47^{b}±0.01	3.57^{b}±0.01	4.36^{b}±0.01	4.46^{b}±0.01	5.11^{b}±0.02	5.62^{b}±0.01	6.6^{b}±0.01	7.40^{b}±0.01
	Control	3.85^{a}±0.04	4.04^{a}±0.03	4.64^{a}±0.03	4.86^{a}±0.01	5.72^{a}±0.02	7.02^{a}±0.01	7.31^{a}±0.01	7.92^{a}±0.01
	Mean	3.66±0.02	3.80±0.02	4.50±0.02	4.66±0.01	5.41±0.02	6.32±0.66	6.96±0.01	7.66±0.01
	CV%	0.68%	0.52%	0.44%	0.21%	0.36%	0.15%	0.14%	0.13%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

Weight loss evaluation of mango fruit during storage

The fruit weight loss during storage was statistically significant (P ≤ 0.05) throughout the observation period, as shown in Table 7. The untreated (control) mango fruits experienced the highest weight loss compared to the *Brokin* and *Julie* varieties during storage. Conversely, the *Brokin* and *Julie* varieties exhibited the least weight loss, which was significantly lower than that of the untreated fruits throughout the entire storage duration. Table 7 indicates a consistent increase in weight loss for both treated and untreated mangoes over the storage period. All samples showed a gradual rise in weight loss as storage time progressed. These findings align with those of Martinez-Romero *et al. (*2006) and Valverde *et al. (*2005), who observed that aloe vera served as an effective coating, acting as a physical barrier that minimized weight loss and reduced respiration rates in table grapes and cherries during postharvest storage. Similarly, Zakki *et al. (*2017) documented a gradual weight loss in UTC, Shase, and Hoozua tomato varieties during storage. They attributed the differences in weight loss among varieties on both treated and untreated could be due to variations in pericarp thickness; fruits with thinner pericarps tend to lose more moisture, leading to greater weight loss, while those with thicker pericarps retain moisture more effectively, thus reducing weight loss.

Post-harvest decay of mango fruits during storage

The mean effect of variety and botanicals was significant (P ≤ 0.05) on the post-harvest decay of mango fruits on all the days under observation as shown in Table 8. The untreated mango fruits produced the highest the post-harvest decay than *Brokin* and *Julie* variety during the entire storage period. The lowest post-harvest decay was produced by *Brokin* and *Julie* variety compare to control fruits. However, no significant differences can be seen between control and the treated fruits throughout the storage period. The highest decay percentage was recorded in the control samples at the end of storage period. It has been observed that coating has the ability to prevent the growth of fungi in wide horticultural produces (Tripathi & Dubey, 2004).

Marketability of mango fruits during storage

The mean effect of variety and botanicals was significant (P ≤ 0.05) on the marketability value of mango fruits on all the days under study as shown in Table 9. *Brokin* variety treated with bitter leaf extract produced the highest marketability content than *Julie* variety and this was significantly higher than that produced by the control fruits. The lowest marketability content was produced by control fruit of both *Brokin* and *Julie* variety during the entire storage period. In this study, a general trend of decrease in marketable mango fruits was observed as the storage period advanced which is in agreement with the findings of (Mohammed *et al.,* 1999; Hiru *et al.,* 2008).

Shelf life of mango fruits during storage

The shelf life of mango on days 1, 5, 9, 13, 17, 21 and 25 was not significant at (P ≥ 0.05) as presented in Table 10. *Brokin* variety treated with bitter leaf extract produced the highest shelf life compare to *Julie* variety and this was significantly higher than that produced by the control fruits. The shelf life of treated mango fruits increased from days 1 to 25 while the controls increased from days 1 to 17, but no significant differences were observed between the treatments and the controls. This may be due to their capacity to reduce postharvest decay incidence (Badawy & Rabea, 2009). Similar results were reported by (Mandal *et al.,* 2018). They stated that waxed coated tomato fruits got maximum shelf life (26.33 days) followed by fruits coated with chitosan at 2% (22.00 days).

Temperature (˚C) **evaluation during the storage duration**

The temperature of the storage room ranged from 24 °C to 26.6 °C in the mornings, 30.0 °C to 35.0 °C in the afternoons and 25.0 °C to 26.8 °C in the evenings as shown in Table11. Temperature (˚C) evaluation of the storage room within the storage period showed that there was no significant difference (p > 0.05) in temperature between mornings, afternoons and evening except on days thirteen and seventeen. The temperature in the afternoon was higher compared to the temperature in the morning and evening on all the days under observation as displayed in Table 11. On day thirteen and seventeen, the temperature in the morning was higher (25.8±0.13) (25.9±0.01) compared to the temperature in the evening (25.5±0.13) (25.3±0.01). The high temperature in this study can be attributed to seasonality. The results are in agreement with the findings reported by (Liamngee, *et al.,* 2018). According to the report it was observed that tomato fruits were shrinking during storage. Respiration and metabolic activities within harvested climacteric fruits like mango are directly related to the temperature of the ambient environment.

Isolation and identification of fungi causing postharvest decay of mango fruits during storage

A total of three fungi namely *Aspergillus niger, Botryodiplodia theobromae*, *Colletotrichum gloeosporioides were* isolated and identified from decaying mango fruits during storage.

Characterization and identification of fungi isolated from mango samples in storage.

Aspergillus niger, it grows very fast on PDA media. Initially, it has white mycelia that turn black after 2 - 3 days and produces radial fissure. They possess conidiophore that consists of vesicles, and phialide borne on metulae and produce profuse chains of globose spores. They mature to produce spores in 3 - 4 days. *Botryodiplodia theobromae* the cultural and morphological characteristics revealed that they isolate produced mycelium which was initially white and turned dark as the culture aged. Mycelia grew and filled the entire 9 mm plate in 4 days. The hyphae were initially hyaline and turned dark, and were septated. *Colletotrichum gloeosporioides* the cultural and morphological characteristics revealed that they colonies of isolates were initially white, which turned grey or remained white as the culture aged. Mycelium grew and filled the entire 9 mm petri dish in 9 days. The result of this study revealed the presence of three different fungal isolates from deteriorating mango fruits. The fungal organisms isolated and identified from decaying mango fruit during the storage period were *Colletotrichum gloeosporioides, Botryodiplodia theobromae*, *Aspergillus niger* which *was* ubiquitously present in all examined mango samples, signifying their widespread prevalence and potential involvement in the initiation of infection in the rotten fruits depict that they are spoilage agent. This is in conformity with the findings of (Ewekeye *et al.,* 2013; Chukunda & Offor 2015). Mailafia et al. (2017), who isolated and reported *Aspergillus niger* as the most dominant mycoflora associated with spoilage of fruits. Okereke et al. (2010) reported that *A. niger*, *Alternaria* spp, *Botryodiplodia theobromae* and *C. gloeosporoides* were isolated from the spoilt mangoes fruit. However, the value obtained for the prevalence of *A. niger* caused a disease called black mold on certain fruits and produced potent mycotoxins called ochratoxins that can be harmful to human beings and animals.

Table 7: Weight loss evaluation of mango fruit during storage

Variety	Botanical	Day 0	Day1	Day5	Day9	Day13	Day17	Day21	Day25
Brokin	Bitter leaf	0.00±0.00	0.64±0.08	1.77^{b}±0.92	2.10^{b}±0.18	2.17^{b}±0.33	2.40^{b}±0.19	2.63^{b}±0.98	2.92^{b}±0.55
	Control	0.00±0.00	0.85^{ab}±0.13	3.16^{a}±0.63	3.34^{a}±1.33	5.12^{a}±0.36	5.24^{a}±0.52	5.34^{a}±0.49	6.16^{a}±1.51
	Mean	0.00±0.00	0.75±0.11	2.46±0.77	2.72±0.75	3.64±0.34	3.82±0.35	3.98±0.73	4.54±1.03
	CV%	0.00%	0.14%	31.50%	27.75%	9.34%	9.29%	18.70%	22.68%
Julie	Bitter leaf	0.00±0.00	1.43^{b}±0.34	3.24^{b}±0.11	3.28^{b}±0.60	3.46^{b}±0.03	3.45^{b}±0.47	3.54^{b}±0.94	3.67^{b}±0.86
	Control	0.00±0.00	3.62^{a}±0.49	6.42^{a}±0.83	7.32^{a}±0.14	7.46^{a}±0.76	7.54^{a}±0.15	7.78^{a}±0.69	7.93^{a}±1.47
	Mean	0.00±0.00	2.52±0.83	5.39±0.13	5.30±0.37	5.46±0.39	5.49±0.31	5.66±0.82	5.80±1.17
	CV%	0.00%	32.93%	2.41%	6.98%	7.14%	5.64%	14.39%	20.17%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at (P ≤ 0.05)

Table 8: Post-harvest decay of mango fruits during storage

Variety	Botanical	Day 0	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	10.25^{b}±0.10	25.10^{b}±0.05	73.10^{b} ±0.10	100.00^{a}±0.00
	Control	0.00±0.00	0.00±0.00	0.00±0.00	13.22^{a}±0.15	23.11^{a}±0.04	73.12^{a}±0.08	100.00^{a} ±0.0	100.00^{a}±0.00
	Mean	0.00±0.00	0.00±0.00	0.00±0.00	13.22±0.15	16.68±0.07	49.11±0.06	6.79±0.28	100±0.00
	CV%	0.00%	0.00%	0.00%	1.13%	0.41%	50.12%	0.13%	0.00%
Julie	Bitter leaf	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	12.48^{b}±0.15	26.12^{b}±0.07	75.13^{b} ±0.12	100.00^{a}±0.00
	Control	0.00±0.00	0.00±0.00	0.00±0.00	15.29^{a}±0.14	25.38^{a}±0.08	75.26^{a}±0.06	100.00^{a}±0.00	100.00^{a}±0.00
	Mean	0.00±0.00	0.00±0.00	0.00±0.00	15.29±0.14	25.17±0.11	50.69±0.06	87.56±0.12	100±0.00
	CV%	0.00%	0.00%	0.00%	0.91%	0.45%	0.11%	0.13%	0.00%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at (P ≤ 0.05)

Table 9: Marketability of mango fruits during storage

Variety	Botanical	Day 0	Day1	Day5	Day9	Day13	Day17	Day21	Day25
Brokin	Bitter leaf	1.33±0.02	2.46^{a}±0.02	4.43^{a}±0.03	5.39^{a}±0.07	7.12^{a}±0.01	6.09^{a}±0.01	5.67^{a} ±0.17	4.8^{a}±0.02
	Control	1.41^{a}±0.11	2.39^{b}±0.03	4.05^{b}±0.05	4.88^{b}±0.20	6.39^{b}±0.16	5.02^{b}±0.15	4.32^{b} ±0.28	2.39^{b}±0.03
	Mean	1.37±0.06	2.42±0.02	4.24±0.04	5.13±0.13	6.75±0.08	5.55±0.08	4.99±0.22	3.62±0.02
	CV%	4.37%	0.01%	0.94%	2.63%	1.25%	0.01%	4.50%	0.69%
Julie	Bitter leaf	1.24±0.02	2.35^{a}±0.02	4.41^{a}±0.03	5.30^{a}±0.01	7.06^{a}±0.01	4.92^{a} ±0.01	5.46^{a} ±0.21	4.69^{a} ±0.02
	Control	1.31^{a}±0.11	2.19^{b}±0.03	3.97^{b}±0.05	4.75^{b}±0.09	6.25^{b}±0.21	3.92^{b}±0.12	3.82^{b}±0.10	2.19^{b}±0.03
	Mean	1.27±0.06	2.27±0.02	4.19±0.04	5.04±0.05	5.32±0.20	4.42±0.06	4.64±0.15	3.44±0.02
	CV%	4.72%	0.88%	0.95%	3.44%	0.99%	1.47%	3.34%	0.72%

Values represent means of triplicate values ± s∂ (standard deviation)

Means with different superscripts on the same column are significantly different at (P ≤ 0.05)

Table 10: Shelf life of mango fruits during storage

Variety	Botanical	Day 1	Day 5	Day 9	Day 13	Day 17	Day 21	Day 25
Brokin	Bitter leaf	1.00±0.00	5.00±0.00	9.00±0.00	13.00±0.00	17.00±0.00	21.00±0.00	25.00±0.00
	Control	1.00±0.00	5.00±0.00	9.00±0.00	13.00±0.00	17.00±0.00	21.00±0.00	25.00±0.00
	CV%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Julie	Bitter leaf	1.00±0.00	5.00±0.00	9.00±0.00	13.00±0.00	17.00±0.00	21.00±0.00	25.00±0.00
	Control	1.00±0.00	5.00±0.00	9.00±0.00	13.00±0.00	17.00±0.00	21.00±0.00	25.00±0.00
	CV%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Values represent means of triplicate values ± s∂ (standard deviation) NS - No significant differences

Table 11: Temperature of the store during storage of mango fruits

Time	**Days of temperature observation**						
	Day 1	**Day 5**	**Day 9**	**Day 13**	**Day 17**	**Day 21**	**Day 25**
Morning	26.6±0.05	26.2±0.05	26.0±0.13	25.8±0.13	25.9±0.01	25.0±0.01	24±0.01
Afternoon	35.5±0.01	35.0±0.01	34.5±0.01	33.0±0.01	32.0±0.01	30.5±0.01	30.0±0.01
Evening	26.8±0.05	26.5±0.05	26.0±0.13	25.5±0.13	25.3±±0.01	25.1±0.01	25±0.01
Mean	29.63±0.11	29.23±0.11	28.16±0.96	28.1±0.96	27.6±0.10	26.86±0.10	26.33±0.10
CV	0.41%	0.37%	3.4%	3.41%	0.37%	0.37%	0.37%

Values represent means of triplicate values ± s∂ (standard deviation)

CONCLUSION

The results obtained in this study indicate that bitter leaf extract can prolong the shelf life and maintain the quality of mango fruits as compared to the untreated samples. This finding offers foundational knowledge on the application of plant leaves extract for post-harvest preservation of mango fruits. Further investigations are recommended to identify the phytochemicals in the leaf extract that may explain its effects on the mango fruits.

Conflict of Interest

The authors declare no conflict of interest.

Funding for the project

The research did not receive any specific grant from funding agencies in the public, commercial or non-profit sectors.

REFERENCES

Abbasi, N. A., Iqbal, Z., Maqbool, M., & Hafiz, I. A. (2009). Postharvest quality of mango (Mangifera indica L.) fruit as affected by Chitosan coating. *Pakistan Journal of Botany,* 41(1): 343-357.

Ali S. M. Y., Hossain M. M., Zakaria M., Hoque M. A., & Ahiduzzaman M. (2019). Postharvest losses of mangoes at different stages from harvesting to consumption. *International Journal Bussiness Social Scientific Research,* **7**: 21-26.

Ali, A., Maqbool, M., Ramachandran, S., & Alderson, P. G. (2010). Gum Arabic as a novel edible coating for enhancing shelf – life and improving postharvest quality of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biological Technological,* 58: 42–47.

Barnett, H. L., & Barry, B. (1999), Illustarted genera of imperfect fungi, 4th ed. t. paul, Minn., APS press, pp. 23-24.

Badawy, M. E. I., & Rabea, E. I. (2009). Potential of the biopolymer chitosan with different molecular weights to control postharvest gray mould of tomato fruit. *Postharvest Biology and Technology,* 51(1): 110- 117.

Baloch, M. K., & Bibi, F. (2012). Effect of harvesting and storage conditions on the postharvest quality and shelf life of mango (*mangifera indica* L.) fruit. *South African Journal Botanical,* 83: 109-116.

Chukunda, F. A., & Offor, U. S. (2015). Studies of Seed-borne pathogen of African breadfruit (*Treculia africana*). *International Journal of Agriculture and Earth Science,* 1 (8): 90-96.

El-Anany, A. M., Hassan, G. F., Rehab, A., & Ali, F. M. (2009). Effects of edible coatings on the shelf life and quality of anna apple (*Malus domestica* Borkh.) during cold storage. *Journal Food Technology,* 7: 5-11.

Ewekeye, T. S., Oke, O. A., Quadri, A. L., Isikalu, A. O., Umenwaniri, M .O., & Durosinmi, M. L. (2013). Studies on post-harvest deterioration of some fruits and vegetables in selected markets in Lagos State, Nigeria. *American Journal of Research Communication,* 1: 209-223.

FAOSTAT, (2007). FAO Statistics, Food and Agriculture Organization of the United Nations, Rome, Italy. http://faostat.fao.org/.

FAOSTAT, (2012). Food and Agriculture Organization of the United Nations. Statistical Production/crops. http://faostat3.fao.org/browse/Q/QC/E, (accessed on 30th October 2015).

Food and Agriculture Organization (FAO). (2021). FAOSTAT Statistical Database. Retrieved from [http://www.fao.org/faostat] (http://www.fao.org/faostat)

Hiru, G., Seyoum, T., & Kebede, W. (2008). The effect of cultivar, maturity stage and storage environment on quality of tomatoes. *Ethiopian Journal of Food Engineering,* 87(4): 467-468.

Ibitoye, A. A. (2005). Laboratory manual on basic methods in plant analysis. Concept IT and Educational Consults, Akure, Nigeria. 2-3.

Jahun, B. G., Abdulkadir, S. A., Musa, S. M., & Umar, H. (2016). Assessment of evaporative cooling system for storage of vegetables. *International Journal of Science and Research*, 5(1): 1197-1203.

Kimura, M., & Rodriguez-Amaya D. B. (2004). Harvest plus handbook for carotenoids analysis. Harvest plus-IFPRI, Washington DC. 1-2.

Kharwade, S. B., Joshi, V. R., Dighe, S. S., & Kad, V. P. (2022). Effect of edible coatings and packaging materials on shelf-life and quality of mango (*Mangifera indica* L.) cv. Kesar. *The Pharmacology Innovation Journal,* **11**: 714 - 723.

Kumar, N., Pratibha, N., & Petkoska, T.A. (2021). Improved shelf life and quality of tomato (Solanum lycopersicum L.) by using chitosan- pullulan composite edible coating enriched with pomegranate peel extract. *ACS Food Science & Technology,* 1: 500

Lebaka, V.R., Young-Jung, W., Weibing, Y., & Mallikarjuna, K. (2021). Nutritional Composition and Bioactive Compounds in Three Different Parts of Mango Fruit. *Environ Res Public Health,* 18(2):74.

Liamngee, K., Iheanacho, A. C., & Kortse, P. A. (2018). Effect of Organic Preservatives on Postharvest Shelf Life and Quality of Tomato Fruits during Storage. *Asian Journal of Research in Crop Science,* 2(1): 1-34.

Liamngee, K., Akomaye, M. U., & Okoro, J. K. (2015). Efficacy of some Botanicals in the Control of Fungi causing Postharvest rot of yam in Katube Market, Obudu, Nigeria. IOSR *Journal of Pharmacy and Biological sciences,* 10(6): 11- 41.

Mailafia, S., Okoh, G. R., Hamza, O., Olabode, K., & Osanupin, R. (2017). Isolation and identification of fungi associated with spoilt fruits vended in Gwagwalada market, Abuja, Nigeria. *Veterinary World*, 10: 393-397.

Mandal, D., Lalhmingchawii, C., Hazarika, T. K., & Shukla, A. C. (2018). Effect of Chitosan, Wax and Particle film Coating on Shelf life and Quality of tomato cv. Samrudhi at ambient storage. *Research journal of Agricultural Sciences,* 9(1): 111-116.

Martinez-Romero, D., Alburquerque, N., Valverde, J. M., Guillen, F., & Castillo, S. (2006). Postharvest cherry quality and safety maintenance by *Aloe vera* treatment: A new edible coating. *Postharvest Biology Technology*, 39: 93-100.

Mohammed, M., Ramaswammy, H. S., & Maftoonazad, N. (1999). Pectin based edible coating of shelf-life extension of Ataulfo Mango. *Journal of Food Processing Engineering,* 35: 572- 600.

Ntsoane, M. L., Sivakumar, D., & Mahajan, P. V. (2020). Optimisation of O2 and CO2 concentrations to retain quality and prolong shelf life of 'shelly' mango fruit using a simplex lattice mixture design. *Biosystems Engineering Journal,* 192: 14–23.

Ogo-Oluwa, A., & Liamngee, K. (2016), "Evaluation of bitter leaf (*Vernonia amygdalina*) extract in the inhibition of fungi causing post-harvest rot of tomato fruits in Makurdi, Benue State, Nigeria", *Der Pharmacia Lettre*, Vol. 3 No.11, pp. 69-73.

Ranganna, B., Ramya, K. G., Kalpana, B., & Veena, R. (2014). Development of cold extruded products (Vermicelli and Pasta). *International Journal of Agricultural Engineering*, 7(2): 360-364.

Sauco, V. G. (2004). Mango production and world market: current situation and future prospects. *ActaHorticulturae,* 1:107–16.

Shah, K. A, Patel, M. B., & Patel, R. J. (2010). *Mangifera Indica* (Mango). *Pharmacogn Rev,* 4: 42–48.

Singh, S. K., Sharma, M., & Singh, P. K. (2018c). Yield, fruit quality and leaf nutrient status of aonla as influenced by intercropping under integrated nutrient management. *Journal Crop Weed,* 14: 09-13.

Suwapanich, R., & Haewsungcharern, M. (2005). Effect of storage temperature on thermal properties of mango cv. Nam Dok Mai Si Thong. Conference on International Agricultural Research for development, Tropentag, Stuttgart Hohenheim.

Tigist, M., & Wosene, A. (2015). Effect of hot water treatment on reduction of chilling injury and keeping quality in tomato (*Solanum lycopersicum* L.) fruits. *Journal of Stored Products and Postharvest Research,* 7(7): 61-68.

Tigist, M., Workneh, T., & Woldetsadik, K. (2011). Effects of variety on the quality of tomato stored under ambient conditions. *Journal Food Science Technological,* 50: 477-486.

Tigist, M., Workneh. T, S., & Woldetsadik, K. (2013). Effects of variety on the quality of tomato stored under ambient conditions. *Journal of Food Science and Technology,* 50(3): 477- 486.

Tripathi, P., & Dubey, N. K. (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. *Postharvest Biology and Technology*, 32(3): 235–245.

Umesh, A. K., Shreshta, Srivastava, & Shrestha. (2017). Ripening regulation and post-harvest life improvement of banana cv. Malbhog using plant extracts and modified atmosphere package. *The Asian Journal of Horticulture,* 12: 255-259.

Valverde, J. M., Valero, D., Romera, D. M., Fabian, N., Guillean, C., Castillo, S., & Serrano, M. (2005). Novel edible coating based on Aloe vera gel to maintain table grape quality and safety. *Journal of Agriculture, food Chemistry,* 53: 7807–7813.

Wani, A. A., Singh, P., Gul, K., Wani, M. H., & Langowski, H.C. (2014). Sweet cherry (*Prunus avium*): critical factors affecting the composition and shelf life. *Food Package Shelf Life,* 1(1): 86-99.

Yahia, E. M. (2011). Postharvest Biology and Technology of Tropical and Subtropical Fruits. Woodhead Publishing.

Yaman, O., & Bayoindirli L. (2002). Effects of an edible coating and cold storage on shelflife and quality of cherries. *Lebnsmittel Wissenschaft Und. Technologie,* 35: 146-150.

Zakki. Y. H., Kator, L., Ameh L.O., & Terna, D.A. (2017). Effect of Neem leaf powder on post-harvest shelf life and quality of tomato fruits in storage. *International Journal of Development and Sustainability, 6: 1334-1349.*

Zhong, Q. P., Xia, W. S., & Jiang, Y. (2006). Effects of 1-methylcyclopropene treatments on ripening and quality of harvested sapodilla fruit. *Food Technological Biotechnological,* 44: 535–539.