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Characterization and Use of Lemon Grass Extracts on Shelf-Life Extension and Quality Stabilization of 'Broken' Mango Variety (*Mangifera Indica* L.) Fruits Sold in Benue State Nigeria

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ABSTRACT

Chemical and biological characterization of lemon grass methanolic extract was carried out and results of the GC-MS reveals the presence of many compounds with antimicrobial, antifungal and antioxidant activities. Among the compounds present in the lemon grass extract include; Hexadecanoic acids, palmitoleic acid, selin - 6 - en - 4 alpha - ol, 5-octadecene, 6-tridecen, methyl ester,2,6-octadiene, octadecenoic acid, eicosane aldehyde amongst others. These compounds attribute to the potency of *C. citrates* (lemon grass) as an antimicrobial and antioxidant natural bio-product that can be widely used in food preservation as an alternative to synthetic compounds. Results of the antimicrobial analysis reveals that, Lemon grass was most effective on *klebsiella* (15.00±1.41) mm followed by staphylococcus (14.50±2.12) mm and *proteus* species (14.50±2.12) mm, this explains the ability of lemon grass to preserve mango thereby extending its shelf-life. In addition, FTIR result of the treated and untreated fruit did not show any difference in the physicochemical composition of the mango fruit during storage. Result of the storage studies showed that broken mango had a shelf-life of 51 days as against 12 days for the control, result of the physiochemical characteristics showed that the pH was lowest at zero day of storage and it slowly increased with the advancement of storage period. Control (that is, untreated sample) had the highest pH until day 12 while that of lemon grass was up to day 51. Titratable acidity (TA) showed a gradual decrease with storage time. Total soluble solids (TSS) increased with storage time. The sensory analysis reveals that lemon treatment showed best scale point of 1 for all parameters whereas controlled samples showed poor scale point. Results of the weight loss indicates that fruits treated with the extract showed lower percentage weight loss as compared to the control generally, weight loss increased with storage time throughout the storage period. On a whole, lemon grass has proven to be a good and cheap alternative method of preventing post-harvest decay and loses through preservation and shelf-life extension of the fruits upon treatment with the extract.

Key words: Lemon grass, 'broken' mango, shelf-life, storage time, post-harvest loss

Introduction

In tropical regions, mango (*Mangifera indica* L.) is a renowned fruit and important economic commodity, appreciated for its nutritional value, excellent flavour, and extensive culinary uses applications [1]. Post-harvest losses, mainly rooted in spoilage and quality deterioration during storage and transportation, pose a significant challenge to mango production [2].

The effective management of mangoes after harvest significantly determines their shelf life and market value [3]. The climate in this area enables the growth of various mango species, making it a significant contributor to both local consumption and commercial trade. Despite its importance, the post-harvest management of mangoes remains a critical issue, affecting the fruit's shelf life and market value [3].

Ensuring both external and internal quality and delivering an appealing flavour are crucial factors for consumer acceptability of mangoes, prompting the investigation of assorted preservation methods and natural additives for extending shelf life [4]. Lemongrass extract's antimicrobial and antioxidant properties contribute to its ability to extend the shelf life of fruits. Lemongrass, which is abundant with aromatic and medicinal properties in Nigeria [5], is a promising candidate for use in food preservation.

Local resources and traditional knowledge are harnessed in enhancing food fruit preservation techniques using plant-based natural products [7]. The botanical extract, with its antimicrobial properties, can effectively decrease the reliance on harmful chemicals during postharvest treatments of fruits to combat diseases. (Gupta & Jain, 2014, reported a decrease in disease incidents in mangoes treated with these extracts.)[8,9] The botanical extract can provide an excellent opportunity to avoid, replace, or reduce the use of harmful chemicals in postharvest treatment of fruits for controlling various diseases as these extracts have been found to possess several antimicrobial properties [8].

Various attempts have been made on the characterization and use of plant-based natural products in fruits preservation [7]. The botanical extract can provide an excellent opportunity to avoid, replace, or reduce the use of harmful chemicals in postharvest treatment of fruits for controlling various diseases as these extracts have been found to possess several antimicrobial properties [8].

The effect of natural plant products has also been reported on storage of rot mangoes, by (Gupta, N., & Jain, S. K. 2014) [9] where the fruits dipped in the plant extracts showed reduction in the disease's incidence. Alam et al. (2017) [10] and Mosaddad et al. (2023) [11] both found significant antifungal activity for *M. oliefera, S. aromaticum, C. zeylanicum,* ginger (*Z. officinale*), green tea (*C. sinensis*), and neem (*A. indica*) against tested pathogens. Alamgir et al (2018) [12] found that *Azardiractin* in neem oil reinforces pectin's molecular structure by preventing the removal of a methyl group from the α-galactouronic acid residue. storage stabilizes pectin molecules, preventing their breakdown.

Shelf-life of fresh-cut "Fuji" apples was studied using an apple puree-alginate coating containing lemon grass, oregano oil, and vanillin by Farina et al (2020) [13]. Among the coating with coatings tested at 4 °C for 21 days, the one containing vanillin (0.3 % w/w) the best sensory quality. All in the other studied study of antimicrobial coatings, lemongrass extract was found to effectively inhibit the growth of psychrophilic aerobes, yeasts, and moulds.

This study, aiming to prolong mango shelf life and preserve fruit quality, applies lemon grass extract as a natural preservative to the 'broken mango variety' in Benue State, Nigeria. Due to its natural existence, affordability, widespread cultivation, accessibility, eco-friendliness, and safety, lemon grass was selected for this study. The study investigates the ability of lemon grass extract to prevent spoilage, preserve fruit quality, and prolong the shelf life of broken mangoes under local storage conditions.

Materials and methods

Healthy mango fruits of the broken mango variety were collected directly from the farms to avoid mechanical injury, a total of seventy-five fruits were obtained, These fruits were later transported to the Postgraduate research Laboratory of Benue State University, Makurdi for analysis alongside the lemon grass which were collected within the neighbouring environs of the university community.

Sample Pre-treatment

The fruits were properly washed with distilled water to remove dust particles and surface microbial load. They were air dried and weighed individually to record their initial weights before treatment. The plant materials that is, the Lemon grass were air dried and grounded in to powdered form for extraction.

Extraction of the lemon grass

Prior to treatment, each sample was weighed individually after being air-dried. The plant materials that is, the Lemon grass were air dried and grounded in to powdered form for extraction. The powdered samples of the Lemon grass (300.0 g) was extracted using soxhlet apparatus with methanol and n-hexane as the extracting solvents. The crude extracts were obtained by evaporating the extracts under reduced pressure at 90 °C using a rotary vacuum evaporator, then stored in refrigerator at 4 °C in dark bottles until use [14]. The yield was calculated using the given methodology.

$$\text{Yield (\%)} = \frac{weight\ of\ recovered\ extract}{weight\ of\ dry\ powder} \times 100$$

Treatment of the Mango Fruit with the Extracts and Storage

The extracts were prepared in various concentrations (0.5, 1.0, 1.5, 2.0, and 2.5) %, by weighing 0.5, 1.0, 1.5, 2.0, and 2.5 g respectively in 100 cm^3 volumetric flasks, followed by adding distilled water up to the mark with 0.0 % conc. as control [15]. The immersion was done in small plastic containers, immersing fruit by fruit at 5 minutes of immersion time with three replications. Spoilt samples were kept for each replication for carrying out physicochemical analysis. These fruits were stored at ambient temperature in the laboratory. Each treatment composed of 5 mango fruits.

Physicochemical quality parameters of the mango fruits

pH of the mango fruits during storage

The pH of the blended solution was determined at ambient temperature using a pH meter. 25 g of the pulp was blended with about 250.0 cm^3-deionised water for 30 min using a magnetic stirrer [16].

Titratable acidity (TA) of the mango fruits during storage

Titratable acidity was determined by blending the pulp, 25.0 g of it with about 250.0 cm^3 deionised water for 30 minutes using a magnetic stirrer. The TA was then measured without filtration by titration with 0.1 M NaOH to equivalence point. The results was expressed in terms of percentage citric acid. It was calculated by the following formula [17].

$$\text{TA (\%)} = \frac{Nb\ x\ Vb\ x\ Ea\ x\ df\ x\ 100}{Vs}$$

Where:

Nb = normality of the base,

Vb = volume of the base,

Ea = mill equivalent weight of citric acid,

VS = volume of sample,

df = dilution factor

Total soluble solids (TSS) of the mango fruits during storage

The TSS levels of the fruits were assayed by hand refractometer following the AOAC method. The Refractometer screen recorded the total soluble solids directly after the right amount of sample was put on its prism-plate. Results was expressed in Brixº [18].

Vitamin C of the mango fruits during storage

Vitamin C content of the mango pulp was determined by volumetric method [19].

Physiological weight loss of the mango fruits during storage

The weight loss during storage was determined by calculating the difference in weight at every 3 days during the storage period and the initial weight (day zero). The weight loss was expressed in percentage [2].

Sensory evaluation of the mango fruits during storage

The mango samples were evaluated for its acceptability during the storage period. Sensory evaluation, i.e. the visual characteristics of the appearance for skin colour, pulp colour, flavour, and taste were scored in day light by a panel of 5 judges who are familiar with fruit assessment using a 5 point hedonic scale, 5 for best and 1 for worst [21].

Shelf-life (days)

Shelf life of the fruits was measured by counting the number of days from start of storage until when almost all of the samples per replicate have been deteriorated.

Antimicrobial characterization of the lemon grass extracts

Agar Well Diffusion Method was employed for the antimicrobial analysis of the extracts. Mueller Hinton agars for bacteria and for fungi were used. Broth media was measured and dissolved in appropriate volume of distilled water, following the manufacturer's guideline and was sterilized by autoclaving [22].

Pour plate technique was used; about 1.0 cm^3 of the standardized inoculum Was mixed with the medium in a sterile container to ensure that the test organisms were evenly distributed and poured into sterile petri dishes and allowed to gel. Each plate contained equal volume of the media.

The antibacterial activity of the Shea butter was determined in accordance with standard agar-well diffusion method [22]. A Cork borer (0.6 cm) was used to bore wells on the agar medium after which 0.1 cm^3 of the extract solution was dispensed into the wells.

The plates were incubated at 37 °C for bacterial activity, the plates were observed for zones of inhibition after 24 hours. This implies that any clear zone of inhibition observed is due to the activity of the extract.

All organisms exhibited viability with at least 100 % surface of the plate. The second control is to test the activity of the solvent (Hexane) used to dissolve the extract to ensure that the activity is not due to action of solvent on the test organisms. Plates were read by measuring observed clear zones (area without growth) of inhibition around the wells containing the extract.

Measuring rule in millimetre was used to take the measurement from the edge of the well to the end of the clear zone of inhibition. The estimation of MIC and MBC of the crude extracts was carried out by standard method [23].

Minimum Inhibitory Concentration (MIC) and Maximum Bactericidal Concentration (MBC) (Broth diffusion method)

The tubes without bacterial growth were cultured in their appropriate agar and incubated appropriately to check for those that will revive and develop colonies. Those that did not revive and grow were recorded as bactericidal or fungicidal [23]

Phytochemical characterization using Gas Chromatography (GC-MS)

The phytochemical quantification of the crude extracts was done using GC-MS to identify and quantify the bioactive components present in the extracts [24].

Statistical test of significance

All the assays were made in triplicate and the results were expressed as mean ± SD (standard deviation). The mean and standard deviations were presented in bar charts using EXCEL software. The results were subjected to one-way analysis of variance to determine if they were significantly different at $p \leq 0.05$

Results and discussion

The methanol extract of lemon grass extract gave a higher percentage yield of 45.3±0.16, while hexane extract gave a lower percentage yield of 28.85±0.15 as seen in Figure 1.

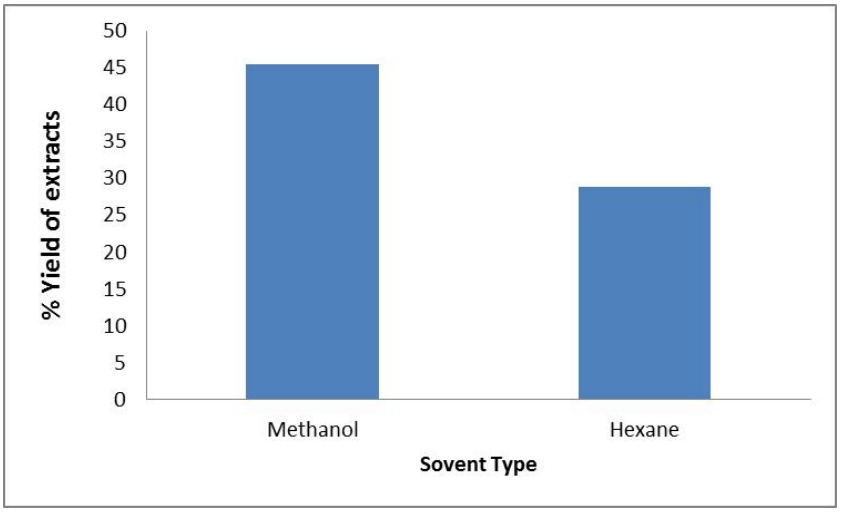

Figure: 1: % Yield of Lemon Grass extract using nHexane and Methanol as Solvents

Methanol was found to give maximum yield in the plant extract. This can be attributed to the higher solubility of compounds in methanol than other solvents, also methanol is a polar solvent.

The results obtained was found to be in agreement with that of Wuryatmo et al (2021) [25] who reported that percentage yields of two cultivars of turmeric extracts and three menthe sp. Extracts prepared by using solvents of different polarity (hexane, di-chloromethane, methanol and water) increased with increase in polarity. Another study by Mwangi, et al (2020) [26], shows that methanol gave the highest percentage yield of plant extract, *Commiphora Africana* - 47.50 %, *C. citrates* – 46.15 % amongst other solvents.

The pH was lowest at zero days of storage and it gradually increased with the advancement of storage period as seen in Figure 2. Control treatment had the highest pH until day 12 while that of lemon grass up to day 51. The increase in the pH value was found to be slow in the fruit treated with lemon grass extract, this exhibits that lemon grass extract helps in slowing down ripening process.

Table 1: pH of 'broken' mango during storage

Time (Days)	Control	Lemon
0	4.25±0.064	-
3	4.45±0.055	4.10±0.031
6	4.69±0.051	4.15±0.031
9	4.84±0.059	4.20±0.035
12	5.01±0.081	4.28±0.036
15		4.36±0.035
18		4.45±0.040
21		4.55±0.047
24		4.61±0.045
27		4.69±0.053
30		4.76±0.040
33		4.88±0.046

36	5.07±0.051
39	5.18±0.045
42	5.24±0.075
45	5.47±0.057
48	5.69±0.056
51	5.80±0.055

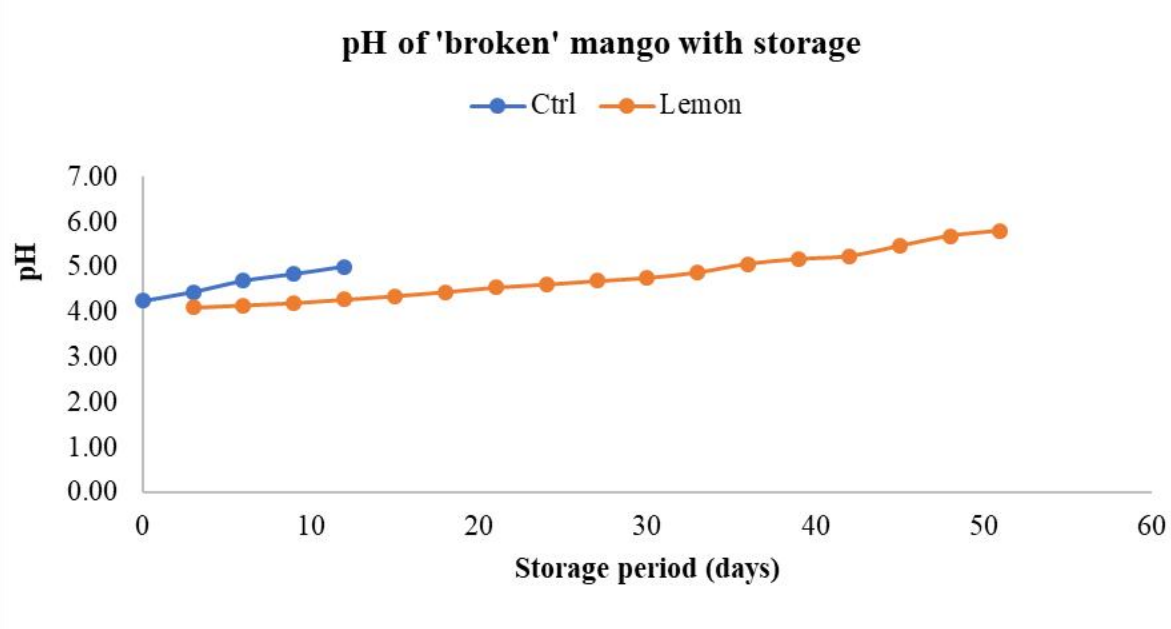

Figure 2: Variation of pH with Storage period of 'Broken' mango

The gradual increase in pH with the advancement of storage period could be due to the breakup of acids with respiration during storage and degradation of citric acid, which in turn might have influenced reduction in acidity due to their conversion into sugars and further utilization in metabolic process in the fruit.

pH measurement terminated at day 51. This finding is aligned with the results previously measured by other researchers such as Kaushik, et al [16], Shrestha *et al* [27] and Gima *et al* [28].

Total soluble solids (TSS) of the 'broken' mango fruits during storage

Total soluble solids (TSS) refers to the concentration of dissolved solids such as sugars and soluble minerals present in fruits. It is an important parameter of fruit quality, it value affects the taste of the fruit because it can indicate the level of sweetness of the fruit**.**

The result of the total soluble solids shows a substantial increase in TSS during storage in the ripening stages as seen in Figure 3. TSS increased with storage time. This could be as a result of accumulation of sugars and organic acids and hydrolysis of polysaccharides (conversion of complex carbohydrates) to simple sugars which constitutes the increase in sweetness, [29].

There was a slow increase of TSS of lemon grass extract treated fruits in comparison to the control, this might be due to the action of lemon grass ingredients that have antifungal properties and also the thin film of lemon grass essential oil on surface of fruits reduced the evapotranspiration and respiration rate and showed minimum decay thus preventing the rapid rise of TSS.

TSS is one of the major maturity index for harvesting of mango fruits. It is one of the main chemical parameter of fruit quality. As mango ripens, soluble sugars (sucrose, glucose and fructose) increase as starch content is hydrolysed to simple sugars

Table 2: TSS of 'broken' mango during storage

Time (Days)	Control	Lemon
0	0.97±0.015	-
3	0.95±0.015	0.94±0.015

6	0.92±0.015	0.92±0.015
9	0.89±0.015	0.89±0.015
12	0.87±0.010	0.88±0.015
15		0.86±0.010
18		0.84±0.010
21		0.81±0.015
24		0.80±0.010
27		0.76±0.015
30		0.74±0.015
33		0.71±0.015
36		0.67±0.012
39		0.65±0.012
42		0.63±0.010
45		0.60±0.010
48		0.61±0.010
51		0.59±0.010
54		0.58±0.010

ROTTEN&DISCARDED

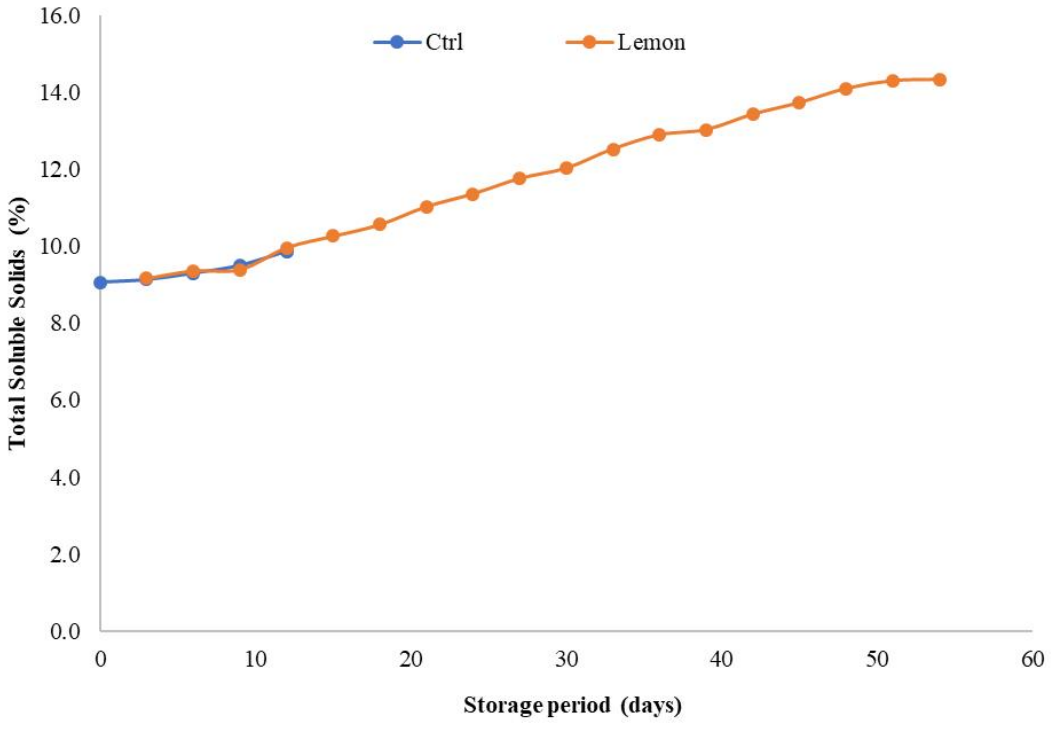

Figure 3: Variation of TSS with Storage period of 'Broken' mango

Total titratable acids (TTA) of the 'broken' mango fruits during storage

The result from Figure 3 shows that the TTA of fruits was maximum at zero days of storage and then a declining trend in titratable acid content was observed with the advancement of storage period. The decrease in acidity during storage (i.e. ripening) could be due to the conversion of citric acid into sugars and their further utilization in various metabolic processes of fruits, Shrestha et al [27].

Fruits preserved with lemon grass extract had higher TA values compared to the untreated (control) throughout the storage period. The decline in TA of lemon grass extract treated fruits was found to be slower due to its effect on the utilization of organic acids in respiration, which delayed the physiological ageing and restricted the starch degradation. Changes of acidity throughout storage time are similar to those reported by other researchers Begum et al [29], Hossain et al, [30], and Islam, et al. [31].

Table 3: Variation of TTA with Storage period of 'Broken' mango

Time (Days)	Control	Lemon
0	0.97±0.015	-
3	0.95±0.015	0.94±0.015
6	0.92±0.015	0.92±0.015
9	0.89±0.015	0.89±0.015
12	0.87±0.010	0.88±0.015
15		0.86±0.010
18		0.84±0.010
21		0.81±0.015
24	ROTTEN&DISCARDED	0.80±0.010
27		0.76±0.015
30		0.74±0.015
33		0.71±0.015
36		0.67±0.012
39		0.65±0.012
42		0.63±0.010
45		0.60±0.010
48		0.61±0.010
51		0.59±0.010
54		0.58±0.010

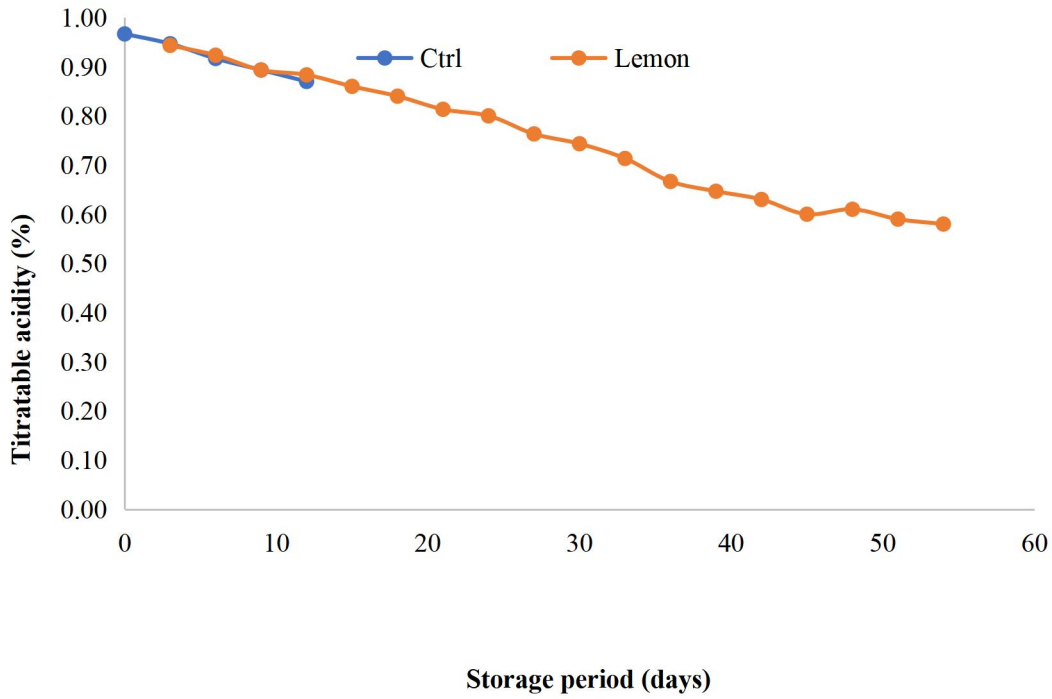

Figure 4: Variation of TTA with Storage period of 'Broken' mango

Vitamin C content of the 'broken' mango fruits during storage

Vitamin C is an essential human diet component required for scurvy prevention, required for the biosynthesis of collagen. The Vitamin C is understood to be the content of ascorbic acid plus dehydroascorbic acid. Figure 5 show a gradual decrease in vitamin C during storage which might be due to the rapid conversion of ascorbic into dehydrascorbic acid. This is also associated with loss of acidity.

This result agrees with the reports of Yousef et al, [32] and Emongor, [33] which reported that ascorbic acid content decreased gradually and significantly during storage due to the influence of many factors (light, temp, air, time). Some researchers have reported that ascorbic first increased then was found to decrease along the storage duration [29]. Lemon grass extract treatment had a little maximum retention of ascorbic acid, this might be due to the ability of the extract in retarding ripening and oxidation processes as well as slowing down the respiration rate of fruits

Table 4: Variation of Vitamin C with storage period of 'Broken' mango

Time (Days)	Control	Lemon
0	16.0±0.153	
3	16.1±0.100	16.1±0.100
6	15.8±0.153	15.9±0.100
9	15.4±0.153	15.7±0.100
12	15.1±0.153	15.6±0.100
15		15.5±0.100
18		15.4±0.100
21		15.2±0.100
24		14.8±0.153
27		14.8±0.100
30		14.6±0.100
33		14.4±0.100

36	14.1±0.153
39	13.9±0.100
42	13.7±0.173
45	13.5±0.100
48	13.1±0.153
51	12.8±0.153
54	12.6±0.100

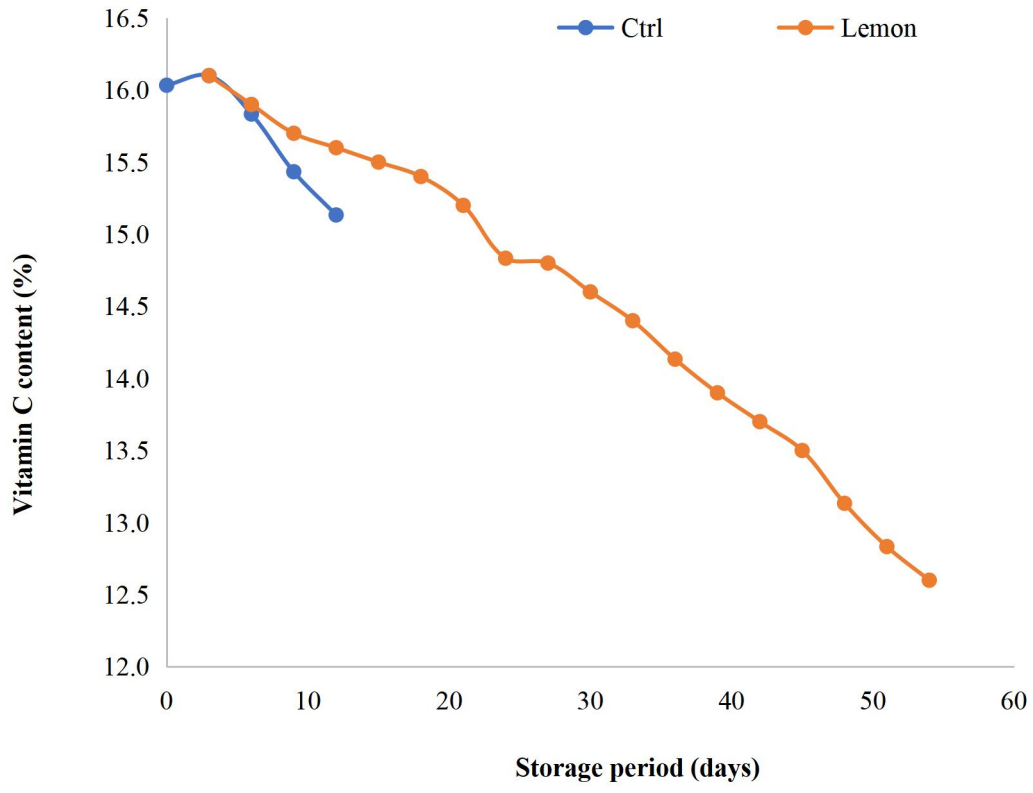

Figure 5: Variation of vitamin C with storage period of broken mango.

Weight loss of 'broken' mango during storage

Fruits preserved with the plant extract showed lower percentage weight loss as compared to the controlled fruits. This could probably be because of the property of the plant extracts that prevents the action of ethylene, which has a direct relation with respiration and fruit ripening. The results also agrees with the report of Lemma et al [35] as well as Kassebi & Korzenszky, [36]

Generally, weight loss increases with storage time throughout the storage period. Weight loss of stored oranges was determined by weighing the fruits before and after each week during storage. The weight loss of stored oranges was later calculated using the formula:

$(A - B)/A \times 100$,

Where A is the weight of the mango fruit before application of the treatment extract and before storage, and B is the weight of mango fruit after application of the treatment extract after storage.

The least weight losses were documented with the beginning of each storage period while the maximum values were observed towards the end of the storage period.

Sensory Evaluation (Organoleptic Evaluation)

The sensory analysis in Table 2 revealed beneficial effects in terms of delaying mango fruit skin browning/darkening and dehydration and maintenance of the visual aspect of the fruit without any detrimental effect on taste, aroma, or flavours. Lemon grass treatment showed best scale point of 1 for all parameters, whereas controlled samples showed poor scale points. The three treatments showed best score for pulp colour, aroma and taste as well.

The untreated or controlled samples showed rancid smell and poor taste, due to the biochemical changes in carbohydrates, proteins, amino acids, lipids and phenolic compounds that are active component of natural additives and can influence the pleasant flavour, aroma and taste. Additives influence the pleasant aroma, flavour and taste of fruits Singh, et al. [37]. Edible coatings protect perishable food products from deterioration by retarding dehydration, suppressing respiration, improving textural quality which help retain volatile flavour compounds and reduces microbial growth.

Table 5: Sensory evaluation of the mango samples treated with *A. indica, C. longa L.* and *C. citratus*

Attributes	**Treatment**	
	C. citratus	**(Control)**
Skin colour	2	5
Pulp colour	1	4
Flavour	1	4
Taste	1	5

Antimicrobial Analysis of the plant extracts

The antimicrobial activity of plant extracts is most likely due to the combined effect of adsorption of polyphenols to bacterial membranes with membrane disruption and subsequent leakage of cellular contents and the generation of hydrogen peroxides from polyphenols.

The results of the antimicrobial analysis which was used to determine the susceptibility or otherwise of the microbes against the extracts of Lemon grass as presented in Table 6 reveals that, Lemon grass was most effective on *klebsiella* (15.00±1.41) mm followed by staphylococcus (14.50 ± 2.12) mm and *proteus* species (14.50 ± 2.12) mm.

lemon grass shows antimicrobial activity to all except *Aspergillus* spp. This explains the ability of this extracts to prolong the shelf life of the fruits by inhibiting such microbes from acting on the mango fruits hence their preservation.

Similar results are reported by Gul, P., & Bakht [38], were the antimicrobial activity of tumeric extracts were tested against *E. coli, S aureus, S. typhi* and *C. albicans* by disc diffusion method. Fatima, *et al* [39] also reported a similar result were the antimicrobial activity of lemon grass extract were tested against bacillus *cereus, E. coli, Klebsiella, staphylococcus aureus* and *Candida albicans* and were all positive.

Table 6: Antimicrobial susceptibility test – Zones of inhibition (mm) of the Lemon grass extract

Microbial specie	**Lemon grass extract**
Staphylococcus	14.50 ± 2.29^{b}
Bacillus	11.50 ± 0.71^{bc}
Klebsiella	15.00 ± 1.41^{a}
Pseudomonas	10.00 ± 0.00
Proteus	14.50 ± 2.12^{ab}
Saccharomyces	12.00 ± 1.41^{abc}
Mucor	10.00 ± 1.41^{c}
Aspergillus	0.00 ± 0.00^{d}
Fusarium	11.00 ± 1.41^{c}
P-value	**0.00**

Values are mean ± standard deviation of triplicate determinations. Means within the sample column bearing different superscripts are significantly different ($p \leq 0.05$)

4.2.3 GC-MS Analysis of lemon grass extract

The chemical constituents of the plant extract were identified using GC-MS. The chromatogram of the methanolic extract of the lemon grass are presented in Figure 6. The mass spectra are also depicted in Table 7. The spectrum of the compounds were compared with the data base spectrum of known compounds stored in the GC-MS library. Results revealed the presence of many compounds with antimicrobial, antifungal and antioxidant activities. Studies have shown that these compounds are antimicrobial preservatives, Duru, & Enyoh [40].

Lemon grass extract revealed quite a number of compounds. The identified compounds comprise mainly hydrocarbons, fatty acids, alcohols, esters and phenols. Among the compounds present in the lemon grass extract include Hexadecanoic acids, palmitoleic acid, selin - 6 - en - 4 alpha - ol, 5-octadecene, 6-tridecen, methyl ester, 2, 6-octadiene, octadecenoic acid, eicosane aldehyde amongst others. These compounds attribute to the potency of *C. citrates* (lemon grass) as an antimicrobial and antioxidant natural bio product widely used in food preservation as an alternative to synthetic compounds, [40].

Lemon grass essential oil protects the sensory properties of food and hinders the activity of microbes, preventing food deterioration, preserving the product quality and extending the shelf life of food. Likewise, this preservative benefit of LEO can be attributed to it active component citral (which is an aldehyde) which constitute the major component of LEO, Mukarran, *et al* [41].

The antioxidant activity of lemon grass is due to the synergistic actions of its active components. A study on the use of ethanolic extract of lemon grass in the storage of cooked and shredded chicken breast revealed that the water activity of the product was not affected by the addition of lemon grass extract Keiling, *et al.,* [42].

Table 7: GC-MS Results for *cymbopogan citratus* extract (lemon grass)

Peak No	Retention Time (s)	Name of compound	Molecular formulae	Molecular weight (g/mol)	Peak area %
1.	6.374	1-methoxy-3-hydroxymethylocatane	$C_9H_{18}O_3$	174.24	0.25
2.	6.732	2,6-Ocatediene	C_8H_{14}	110.20	1.29
3.	6.799	2-methlyl-z,z-13-octadecadienol	$C_{19}H_{36}O$	280.5	1.51
4.	7.587	5-octadecene	$C_{18}H_{36}$	252.5	2.32
5.	7.638	9-octadecadecenal	$C_{18}H_{34}O$	266.5	1.55
6.	7.682	6-tridecene	$C_{13}H_{26}$	182.35	1.55
7.	14.552	Selin-6-en-4 alpha-ol	$C_{15}H_{20}O$	222.37	3.51
8.	21.300	Hexadecanoic acid , methyl ester	$C_{17}H_{20}O$	270.45	0.63
9.	22.993	n-Hexadecanoic acid	$C_{16}H_{32}O$	256.42	1.32
10.	29.270	Cycloeicosane	$C_{20}H_{40}$	280.5(17)	0.07
11.	30.621	Cyclopropaneoctanal,	$C_{11}H_{20}O$	168.28	0.25
12.	31.540	E-9-Hexadecenal	$C_{16}H_{30}O$	238.41	0.27
13.	31.672	Oxacyclotetradecane-2.	$C_{13}H_{22}O_3$	226.31	0.95
14.	32.019	z-8-methyl-9- tetradecenoic acid	$C_{15}H_{28}O_2$	240.38	0.66
15.	33.218	Palmitoleic acid	$C_{16}H_{30}O_2$	254.41	1.24
16.	32.461	7,11-Hexadecadienal	$C_{16}H_{28}O$	236.39	0.38
17.	33.151	13-octadecenal	$C_{18}H_{34}O$	266.5	0.38

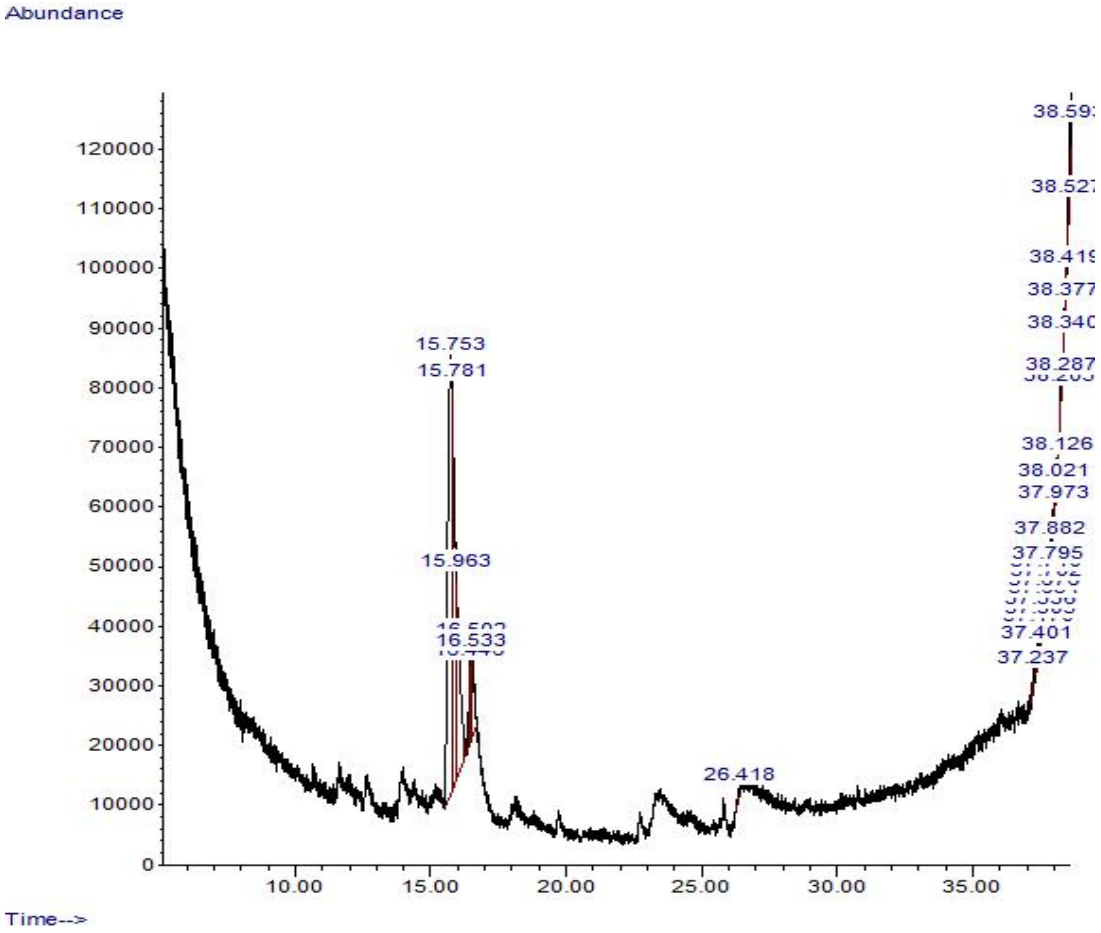

Figure 6: GC-MS chromatogram for *cymbopogan citrates* extract (lemon grass)

FTIR analysis of the mango varieties

Tables 6 present the IR regions and functional groups of 'Broken' untreated and treated with the lemon grass extracts, Figures 7 and 8 on the other hand show the FTIR spectrals of the 'broken' mango both untreated and treated with the plant extracts.

A close look at the FTIR results of the untreated and treated side by side did not actually reveal the emergence of a functional group that was as a result of adsorption or sorption of the preservatives. This submits that coating of these mango fruits with the plant extracts as preservatives did not have any effect on the functional group of the mango fruits also implying that the nutritional quality of the mango fruits were not altered as a result of application of the preservatives.

Table 8: FT-IR spectral data for 'broken' mango, untreated and treated with lemon grass (*C. Citratus*)

Group Frequency (cm^{-1})	**Observed frequency cm^{-1}**		**Final group**	**Assignment**
	Control (Untreated)	**Treated with *C. Citratus***		
3500 – 3000	3386	3306	N–H stretch	Amines
			O–H stretch	Carboxylic acid
			C–H stretch	Alkynes
3000 – 2500	2929	2933	C–H stretch of –C–H	Alkyl groups,
			C–H stretch of-CHO	Aldehydes

2500 – 2000	2105	2102	C≡C or C≡N stretch	Alkynes or nitriles
2000 – 1500	1744	1744	C=C	Alkenes
	1636	1636	N–H	Amines, amides.
	1423	1423	C=O stretch	Aldehydes, ketones, acids, acid halides
1500 – 1000	1364	1364	C-O stretch	Acids, esters, anhydrides, alcohols
	1237	1237	C-H bend	
	1178	1278	C=C	Alkyl groups
	1103	1103		Arenes
	1047	1047		
1000 – 500	987	987	C=H bend of CH_2=CH	Vinyl groups, trans alkenes, substituted benzenes
	869	678		
		864		

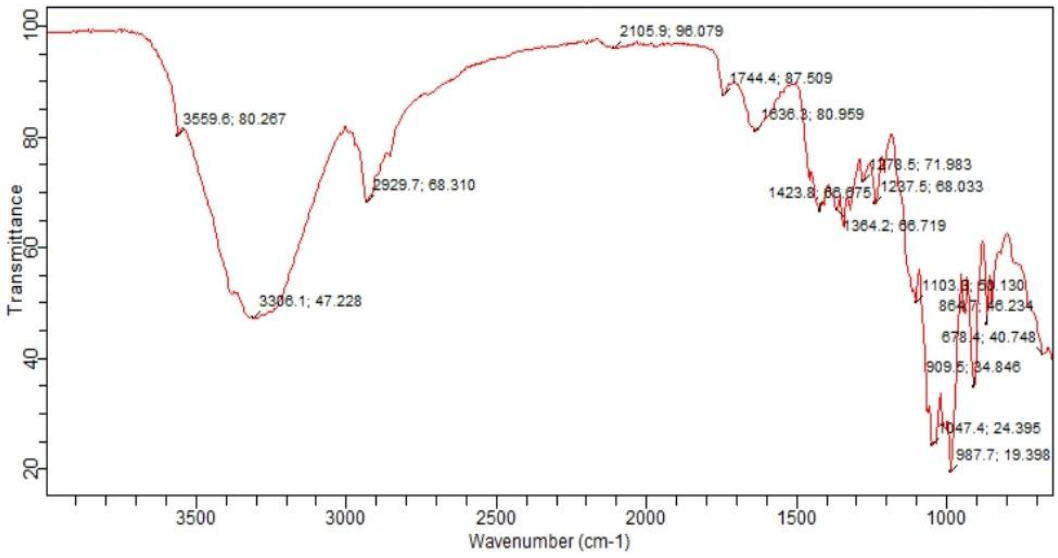

Figure 8: FT-IR spectral of 'Broken' Mango treated with *C. citratus* extract

Shelf-life study of the treated 'broken' mango fruits

Application of the lemon grass extract on the mango and subsequent storage extended its shelf to 51 days as seen in the Figures 1 to 8 above.

This is already explained in the antimicrobial result above (Table 6). Its explains the ability of this extracts to extend the shelf life of the fruits by inhibiting such microbes from acting on the mango fruits and its thin film reducing the evapotranspiration and respiration rate hence their preservation in support of results of Bambalele et al., (2021) [3].

Conclusion

The present study discovered that postharvest immersion of 'broken' mango fruit in plant extract can improve the post-harvest quality and extend the shelf life and at the same time conserving its nutritional quality. The treated mango fruits gave superior performance as compared to the control.

There was least physiological weight loss, maximum ascorbic acid content, maximum acidity and minimum pH in lemon grass extract treatment. This result indicates that the use of lemon grass extract can be a better alternative for maintaining quality and extending post-harvest life of mango in leu of chemicals that are unfriendly to man and environment.

References

[1] Yahia, E. M., de Jesús Ornelas-Paz, J., Brecht, J. K., García-Solís, P., & Celis, M. E. M. (2023). The contribution of mango fruit (*Mangifera indica* L.) to human nutrition and health. *Arabian Journal of Chemistry*, *16*(7), 104860.

[2] Le, T. D., Viet Nguyen, T., Muoi, N. V., Toan, H. T., Lan, N. M., & Pham, T. N. (2022). Supply chain management of Mango (*Mangifera indica* L.) fruit: A review with a focus on product quality during postharvest. *Frontiers in Sustainable Food Systems*, *5*, 799431.

[3] Bambalele, N. L., Mditshwa, A., Magwaza, L. S., & Tesfay, S. Z. (2021). Recent advances on postharvest technologies of mango fruit: a review. *International Journal of Fruit Science*, *21*(1), 565-586

[4] Tavassoli-Kafrani, E., Gamage, M. V., Dumée, L. F., Kong, L., & Zhao, S. (2022). Edible films and coatings for shelf life extension of mago: A review. *Critical Reviews in Food Science and Nutrition*, *62*(9), 2432-2459..

[5] Fatunmibi, O. O., Njoku, I. S., Asekun, O. T., & Ogah, J. O. (2023). Chemical composition, antioxidant and antimicrobial Activity of the essential oil from the leaves of *Cymbopogon citratus*. *American Journal of Essential Oils and Natural Products*, *11*(1), 01-05.

[6] Nxumalo, K. A., Aremu, A. O., & Fawole, O. A. (2021). Potentials of medicinal plant extracts as an alternative to synthetic chemicals in postharvest protection and preservation of horticultural crops: A review. *Sustainability*, *13*(11), 5897.

[7] Nastasi, J. R., Kontogiorgos, V., Daygon, V. D., & Fitzgerald, M. A. (2022). Pectin-based films and coatings with plant extracts as natural preservatives: A systematic review. *Trends in Food Science & Technology*, *120*, 193-211.

[8] Nxumalo, K. A., Aremu, A. O., & Fawole, O. A. (2021). Potentials of medicinal plant extracts as an alternative to synthetic chemicals in postharvest protection and preservation of horticultural crops: A review. *Sustainability*, *13*(11), 5897.

[9] Gupta, N., & Jai, S. K. (2014). Storage behavior of mango as affected by post harvest application of plant extracts and storage conditions. *Journal of food science and technology*, *51*, 2499-2507.

[10] Alam, M. W., Rehman, A., Sahi, S. T., & Malik, A. U. (2017). Exploitation of natural products as an alternative strategy to control stem end rot disease of mango fruit in Pakistan. *Pakistan Journal of Agricultural Sciences*, *54*(3).

[11] Mosaddad, S. A., Hussain, A., & Tebyaniyan, H. (2023). Green alternatives as antimicrobial agents in mitigating periodontal diseases: a narrative review. *Microorganisms*, *11*(5), 1269.

[12] Alamgir, A. N. M., & Alamgir, A. N. M. (2018). Phytoconstituents–active and inert constituents, metabolic pathways, chemistry and application of phytoconstituents, primary metabolic products, and bioactive compounds of primary metabolic origin. *Therapeutic Use of Medicinal Plants and their Extracts: Volume 2: Phytochemistry and Bioactive Compounds*, 25-164.

[13] Farina, V., Passafiume, R., Tinebra, I., Palazzolo, E., & Sortino, G. (2020). Use of aloe vera gel-based edible coating with natural anti-browning and anti-oxidant additives to improve post-harvest quality of fresh-cut 'fuji'apple. *Agronomy*, *10*(4), 515.

[14] Kumoro, A. C., Wardhani, D. H., Retnowati, D. S., & Haryani, K. (2021). A brief review on the characteristics, extraction and potential industrial applications of citronella grass (*Cymbopogon nardus*) and lemongrass (*Cymbopogon citratus*) essential oils. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1053, No. 1, p. 012118). IOP Publishing.

[15] Ebrahimi, F., & Rastegar, S. (2020). Preservation of mango fruit with guar-based edible coatings enriched with Spirulina platensis and Aloe vera extract during storage at ambient temperature. *Scientia Horticulturae*, *265*, 109258.

[16] Kaushik, N., Nadella, T., & Rao, P. S. (2015). Impact of pH and total soluble solids on enzyme inactivation kinetics during high pressure processing of mango (Mangifera indica) pulp. *Journal of Food Science*, *80*(11), E2459-E2470.

[17] Negi, P. S. (2012). Plants extract for the control of bacterial growth: Efficacy, stability and safety issues for food application. *International Journal of Food Microbiology.* 15 (6): 7 –17.

[18] Ubwa, S. T., Ishu, M. O., Offem, J. O., Tyohemba, R. L., & Igbum, G. O. (2014). Proximate composition and some physical attributes of three mango (Mangifera indica L.) fruit varieties. *International Journal of Agronomy and Agricultural Research*, *4*(2), 21-29.

[19] Lebaka, V. R., Wee, Y. J., Ye, W., & Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *International journal of environmental research and public health*, *18*(2), 741.

[20] Wongmetha, O., Ke, L. S., & Liang, Y. S. (2015). The changes in physical, bio-chemical, physiological characteristics and enzyme activties of mango cv. Jinhwang during fruit growth and development. *NJAS: Wageningen Journal of Life Sciences*, *72*(1), 7-12.

[21] Bernal-Mercado, A. T., Ayala-Zavala, J. F., Cruz-Valenzuela, M. R., Gonzalez-Aguilar, G. A., Nazzaro, F., Fratianni, F., ... & Silva-Espinoza, B. A. (2018). Using sensory evaluation to determine the highest acceptable concentration of mango seed extract as antibacterial and antioxidant agent in fresh-cut mango. *Foods*, *7*(8), 120.

[22] Hassan, H. M., Aboel-Ainin, M. A., Ali, S. K., & Darwish, A. G. G. (2021). Antioxidant and Antimicrobial activities of MEOH Extract of Lemongrass (*Cymbopogon citratus*). *Journal of Agricultural Chemistry and Biotechnology*, *12*(2), 25-28.

[23] Mishra, M. P., Rath, S., Swain, S. S., Ghosh, G., Das, D., & Padhy, R. N. (2017). In vitro antibacterial activity of crude extracts of 9 selected medicinal plants against UTI causing MDR bacteria. *Journal of King Saud University-Science*, *29*(1), 84-95.

[24] Zulfina, S., Fathoni, M. A. N., Poerwanto, R., & Matra, D. D. (2021, December). Characterization of secondary metabolites in kasturi mango (*Mangifera* casturi) using gas chromatography-mass spectrometry. In *IOP Conference Series: Earth and Environmental Science* (Vol. 948, No. 1, p. 012059). IOP Publishing.

[25] Wuryatmo, E., Suri, A., & Naufalin, R. (2021). Antioxidant activities of lemongrass with solvent multi-step extraction microwave-assisted extraction as natural food preservative. *Journal of Functional Food and Nutraceutical*, 117-128.

[26] Mwangi, C., Nimbeshaho, F., Abdulai, Y., Chacha, M. R., Ndirangu, E. G., Ajaiyeoba, E. O., & Kigondu, E. V. (2020). Antimycobacterial activity, cytotoxicity and phytochemical screening of organic extracts of Commiphora africana stem bark from Kenya.

[27] Shrestha, S., Pandey, B., & Mishra, B. P. (2018). Effects of different plant leaf extracts on postharvest life and quality of mango. *International Journal of Environment, Agriculture and Biotechnology*, *3*(2), 239082.

[28] Girma, G., Garo, G., & Fetena, S. (2016). Chemical composition of mango (Mangifera indica L) fruit as influence by postharvest treatments in Arba Minch, southern Ethiopia. *Toxicology and Food Technology*, *10*, 70-77.

[29] Begum, M. L., Ahmed, M., Rahman, M. A., & Islam, M. T. (2023). Pre-harvest bagging and ambient storage influenced fruit quality and post-harvest physiology of mango (cv. Gopalbhog). *Plant Physiology Reports*, *28*(4), 607-619.

[30] Hossain, M. S., Ramachandraiah, K., Hasan, R., Chowdhury, R. I., Kanan, K. A., Ahmed, S., ... & Ahmed, M. (2021). Application of oxalic acid and 1-methylcyclopropane (1-MCP) with low and high-density polyethylene on post-harvest storage of litchi fruit. *Sustainability*, *13*(7), 3703.

[31] Islam, M. R., & Mitcham, E. J. (2024). Changes in raspberry sensory quality after harvest as affected by CO2 atmospheres. *Food Packaging and Shelf Life*, *45*, 101335.

[32] Yousuf, B., Srivastava, A. K., & Ahmad, S. (2020). Application of natural fruit extract and hydrocolloid-based coating to retain quality of fresh-cut melon. *Journal of Food Science and Technology*, *57*, 3647-3658.

[33] Emongor, V. E., & Ramagonono, G. (2019). Storage temperature influences postharvest quality of wild plum (Ximmenia americana L.) Fruit. *Ghana Journal of Science*, *60*(2), 1-10.

[34] Ribeiro, L. R., Leonel, S., Souza, J. M. A., Garcia, E. L., Leonel, M., Monteiro, L. N. H., & Ferreira, R. B. (2020). Improving the nutritional value and extending shelf life of red guava by adding calcium chloride. *Lwt*, *130*, 109655.

[35] Workineh, M., & Lemma, H. (2020). Post harvest loss management and quality control of fruits and vegetables in Ethiopia for securing food and nutrition—A review. *Food Sci. Qual. Manag*, *100*, 21-28.

[36] Kassebi, S., & Korzenszky, P. (2021). The effect of post-harvest storage on the weight of Golden Delicious apples. *Science, Technology and Innovation*, *13*(2).

[37] Singh, R. P., Piloo, N., Yadav, S., & Singh, K. J. (2023). Studies on Biochemical Changes in Immature Mangoes (Mangifera indica L.) cv Konsam Heinou of Manipur using Different Skin Coatings During Storage. *Environment and Ecology*, *41*(3D), 2099-2105.

[38]. Gul, P., & Bakht, J. (2015). Antimicrobial activity of turmeric extract and its potential use in food industry. *Journal of food science and technology*, *52*, 2272-2279.

[39] Hussain, A., Kausar, T., Rehman, A., Batool, A., Saleem, M., Musharraf, T. M., & Arif, M. R. (2023). Evaluation of the phytochemical and medicinal value of lemongrass (Cymbopogon citratus), by conversion into powders and extracts to develop a nutritional bakery product. *Future Integrative Medicine*, *2*(3), 129-140.

[40] Duru, I. A., & Enyoh, C. E. (2020). Comparative analysis of phytochemicals and fatty acids from lemon peel and lemongrass essential oils by GC-FID technique. *J. Med. Plants*, *8*, 178-182.

[41] Mukarram, M., Choudhary, S., Khan, M. A., Poltronieri, P., Khan, M. M. A., Ali, J., ... & Shahid, M. (2021). Lemongrass essential oil components with antimicrobial and anticancer activities. *Antioxidants*, *11*(1), 20.

[42] Kieling, D. D., Delarco, M. F., & Prudencio, S. H. (2021). Lemongrass Extract as a Natural Preservative of Cooked and Shredded Chicken Breast during Storage. *Journal of Culinary Science & Technology*, *19*(1), 55-66.