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(RESEARCH ARTICLE)

Efficacy of plant-based extracts on post-harvest quality of stored mango fruits (M*angifera indica* l.) in Makurdi, Nigeria

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Abstract

Efficacy of plant-based extracts on shelf life and postharvest quality of stored mango fruits was carried out. The experiment was laid out in a CRD with a 2 x 3 factorial experiment replicated 3 times. Healthy mango fruits of two varieties (Julie and Mabrouka) were harvested at harvest maturity and treated by immersing into three treatments Aloe vera gel, Aloe vera bark and a control. The fruits allowed to stay until the fruits were completely coated with the extracts, the stored at ambient temperature. Data obtained from the study was subjected to ANOVA, means were separated using (F-LSD) at 5% level of probability. The study results showed that plant-based extracts had significantly higher (≤0.05) effects on Weight Change, Total Soluble Solids (TSS) (°Brix), Firmness (N/cm), Lycopene (mg/100g), pH, Titratable Acidity (TA) (%), Decay Percentage (%) and Shelf-Life of stored mango fruits as compared to the control. There was no significant difference (≥0.05) in the interaction effect of variety and plant-based on postharvest weight change of fruits at 1 and 3WAS but significant effect was recorded on 0, 2 and 4WAS. TSS of fruits steadily increased in storage, however, the main effect of plant-based extracts as well as the interaction effect of variety and plant-based extracts on the TSS of mango fruits during storage was not significant only on OWAS. At the end of the storage Julie treated with Aloe vera gel (24.70) (°Brix), recorded the highest TSS. At the end of the storage, decay percentage of the untreated fruits was (18.78%), while fruits treated with Aloe vera extract (5.00%) and bark of Aloe vera (15.00%). These botanicals are environmentally friendly, cost effective, easy to produce and safe for consumers. Bio-based extracts of Aloe vera gel and Bark are recommended in the storage of flesh mango fruits.

Keywords: Mango; Plant-based extracts; Aloe vera gel; Fruit quality; Shelf life

1. Introduction

Mango (*Mangifera indica*), a member of the family *Anacardiaceae*, is recognizes as one of the most important economically important climacteric fruits worldwide (Le *et al.,* 2022; Ntsoane *et al.,*2019). Mango is regarded as one of the most desirable fruits owing to its appealing color, distinctive flavor and high nutritional value. It is rich in carbohydrate, beta-carotene, vitamins C, B1, B2 and is an important source of polyphenols (Passanet *et al.,* 2019). In Nigeria, the majority of mango production is consumed fresh, despite the country ranking 9th among the world's top ten mango-producing nations. The main producing states include Benue, Nasarawa, Plateau, Jigawa, Yobe, Kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa, Taraba and FCT. However, Benue State is a top producer in the country (Anda & Anda 2023; Altendorf, 2017). The postharvest losses could reach a value of 50% depending on mango varieties,

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postharvest handling, and technologies (Le *et al.,* 2022; Perumal *et al.,* 2021). Postharvest technologies, packhouse management were noted to show significant impacts on the retention of mango quality throughout the supply chain (Sivakumar *et al.,* 2011). After harvesting, mangoes are easily perishable due to postharvest disease pathogens (Perumal *et al.,* 2021) and rapid ripening of mango leads to high susceptibility to post-harvest losses (Le *et al.,* 2022; Sivakumar et *al.,* 2011). Furthermore, postharvest pretreatment of mango fruits before the packaging step is one of the critical points in the supply chain to prevent postharvest diseases and delay the ripening process (Le *et al.,* 2022). Various synthetic chemicals like mancozeb, benomyl, carbendazim, and thiabendazol have gained popularity among growers for control of postharvest diseases of fruits for improvement of the storage life (Agbatar *et al*., 2023). According to Shrestha *et al*., (2018) natural plant extracts from higher plants that are non-hazardous to both human health and environment are better alternatives to chemicals for controlling post-harvest diseases of mango fruits. It has been the goal of many plant scientists to find alternatives that are cost effective, non-toxic and eco-friendly with low residual action to prevent pest and disease infections and maintain post-harvest qualities of horticultural fruits (Iorliam and Ugoo, 2026; Iorliam *et al.,* 2025; Agbatar *et al*., 2023). *Aloe vera* gel is applied to fruits as an edible coating and has been widely utilized for a variety of fruits and vegetables. Such coatings confer several beneficial effects, including enhancing surface gloss and colour, reducing weight loss and extending storage and shelf life by inhibiting microbial spoilage (Agbatar *et al.,* 2023; Dang *et al*., 2008). It is on the backdrop of this, that this research was conducted to fill the gap by evaluating the efficacy of *Aloe vera* gel and Bark of *Aloe vera* coatings as an alternative to chemical preservative on the postharvest quality and shelf-life mango fruits at ambient storage condition.

2. Materials and methods

2.1. Experimental Location

The experiment was conducted at the Biological Science Laboratory, Reverend Father Moses Orshio Adasu University Makurdi, formerly Benue State University, Makurdi between June and December, 2019. Makurdi, the capital of Benue State, Nigeria.

2.2. Source of Materials

Healthy Mango fruits of two varieties (Julie and Mabrouka) were manually harvested manually using a secateur to cut the peduncle at the base of the fruits. The mangoes were obtained from a commercial farm at Yandev, Gboko Local Government Area. The samples were immediately transported to the laboratory, where they were sorted and graded for Postharvest analysis.

Aloe vera plants was harvested from Oracle farm, kilometer 4 Naka Road, Makurdi metropolis, to extract both the bark and gel and use for the experiment. Fully expanded, mature, healthy and fresh *Aloe vera* leaves were collected using a sharp knife, washed with clean water, and then with sterile distilled water.

2.3. Preparation of Materials

The tapering tip and short, shar spines along the leaf margins of Aloe vera were removed using a sharp knife. The knife was then inserted into the mucilage layer beneath the green rind, avoiding the vascular bundles. Both the top and bottom ends were cut off, and the *Aloe vera* gel was extracted. After separating *Aloe vera* gel from the outer cortex, this colorless hydro-parenchyma was blended to remove fibers and placed into clean, sterilized glass bottles. These bottles were stored in the refrigerator at 4 - 8ºC until ready for use. The resulting liquid constituted fresh *Aloe vera* gel as reported by Liamngee *et al*., (2018).

The *Aloe vera* bark was thoroughly washed to ensure no gel remained, then pounded in a laboratory mortar, subsequently blended using an electric blender and stored in a refrigerator until use.

The cleaned mango fruits (Julie and Mabrouka) were completely immersed in 100% *Aloe vera* gel and 100% Bark of *Aloe vera* respectively and left until the fruits were fully coated. The fruits were then removed, air-dried, placed in plastic crates and stored at room temperatures.

2.4. Experimental Design

A 2 x 3 factorial experiment laid out in a completely randomized design (CRD) with three (3) replications was used. The factors were two mango varieties (Julie and Mabrouka) and three (3) treatments (*Aloe vera* gel, *Aloe vera* bark and untreated control. This resulted in 18 treatment units. Each unit contained 15 fruits, giving a total of 270 orange fruits for the experiment.

2.5. Data Collection

The treated and control fruits were stored, and data collected over four weeks. Parameters assessed included postharvest weight change, total soluble solid (TSS), firmness, pH, titratable acidity (TA), decay percentage, lycopene content, beta-carotene content, and fruits shelf life.

2.6. Statistical Analysis

Data obtained from the study were subjected to analysis of variance (ANOVA) using GENSTAT statistical package (2015). Treatment means were separated using Fisher's Least Significance Difference (F-LSD) at 5% level of probability.

3. Results

3.1. Preservative Potential of *Aloe vera* gel and Bark of *Aloe vera* on the physical characteristics of Mango Fruits during Storage

3.1.1. Weight Change

The main effect of variety on the post-harvest weight change showed that Mabrouka exhibited a statistically higher weight change compared to Julie variety throughout the period (figure 1 and 2).

When extracts were compared, *Aloe vera* gel produced significantly higher weight on 0 weeks after storage (WAS) (66.29) and 2WAS (56.10) compared to *Aloe vera* bark (65.55 and 51.53 respectively) and the control (52.51 and 40.28). At the end of the storage duration, *Aloe vera* bark (51.60) resulted in a statistically higher weight change than *Aloe vera* gel (46.50) and the control (28.50). The control consistently produced lower weight across all observed weeks.

The interaction effect of variety and plant-based extracts was not significant (P≥0.05) at 1 WAS and 3 WAS; however, a significant effect was recorded on 0 WAS, 2 WAS and 4 WAS (Table 1).

At 0 WAS, Julie treated with *Aloe vera* gel (46.50) produced a higher weight than *Aloe vera* bark (45.50) and the control ((0.00). However, for Julie, *Aloe vera* bark yielded significantly higher weights at 1 WAS (39.86), 2 WAS (37.73) 3 WAS (35.93), and 4 WAS (33.90) compared to *Aloe vera* gel (33.65), (31.57) and (27.90) and the control (34.40), (26.83), (20.63) and (18.90) respectively.

Similarly, for Mabrouka treated with *Aloe vera* gel on 0 WAS (86.08), the weight was significantly higher than that of *Aloe vera* bark (85.60) and the control (0.00). However, for Mabrouka, *Aloe vera* bark at 2 WAS (74.47) and 4 WAS (69.20) produced significantly higher weight than *Aloe vera* gel (71.50 and 65.20) and the control (53.73 and 38.20).

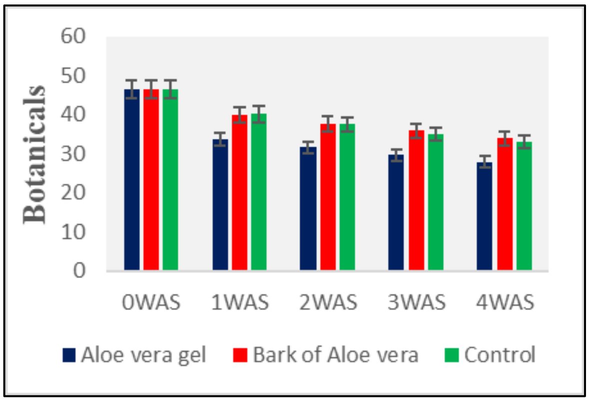

Figure 1 Effect of Botanicals and Julie variety on Mango Weight during Storage

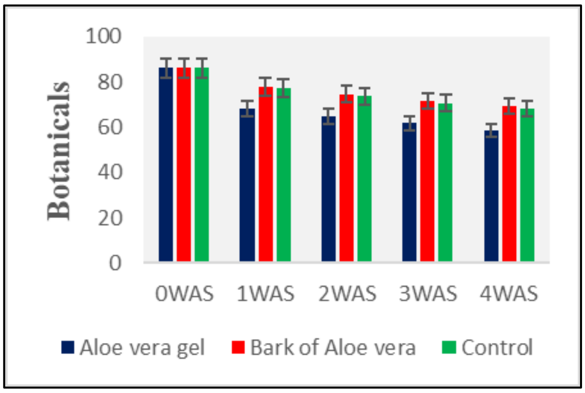

Figure 2 Effect of Botanicals and Mabrouka variety on Mango Weight during Storage

Table 1 Interaction Effect of Variety and Plant-based Extracts on Post-harvest Weight Change of Mango Fruits during Storage

Varieties (V)	Extracts (E)	0WAS	1WAS	2WAS	3WAS	4WAS
Julie	*Aloe vera* gel	46.50	33.65	31.57	29.67	27.90
	Bark of *Aloe vera*	45.50	39.86	37.73	35.93	33.90
	Control	0.00	34.40	26.83	20.63	18.90
Mabrouka	*Aloe vera* gel	86.08	74.90	71.50	68.59	65.20
	Bark of *Aloe vera*	85.60	78.01	74.47	71.60	69.20
	Control	0.00	70.63	53.73	47.40	38.20
F-LSD (P≤0.05)		5.23	NS	5.92	NS	9.81
F.pr		0.423	0.882	0.867	0.837	0.731

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.1.2. Fruit Firmness

Regarding firmness, the main effect of variety on mango fruit firmness during storage showed a decline in both varieties. As shown in figure 3 and 4, firmness decreased from 4.75 to 1.30 in Julie and 4.53 to 1.85 in Mabrouka. At 0 WAS, Julie (4.73) had significantly higher firmness than Mabrouka (.4.53). However, from 1 WAS to 4 WAS, Mabrouka consistently outperformed Julie, with firmness values of 4.4.0, 2.43, 2.20 and 1.85 compared to Julie's 3.98, 2.27, 1.735 and 1.30 respectively. When comparing plant-based extracts, Aloe vera bark produced superior firmness throughout the storage period, and the difference were statistically significant.

The interaction effects between variety and plant-based extracts further clarified these trends. At 1 WAS, untreated (control) Mabrouka (4.60) was statistically different from all other extract treatments. At 3 WAS, Mabrouka treated with *Aloe vera* bark (2.45) showed higher firmness than any other extract treatments. Similarly, at 4 WAS, Mabrouka treated with *Aloe vera* bark retained firmest fruit, and the difference was significant. By the end of the storage period, the combination of Mabrouka with *Aloe vera* bark (2.05) produced the firmest fruit overall, while the untreated Julie control (1.15) produced the least firmness among all variety-extract interactions (Table 4).

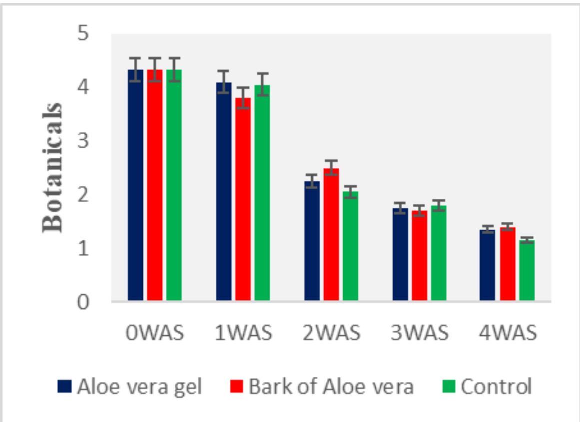

Figure 3 Effect of Botanicals and Julie variety on Mango Fruit Firmness during Storage

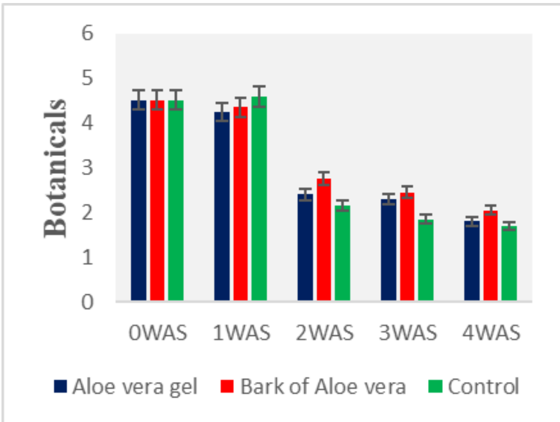

Figure 4 Effect of Botanicals and Mabrouka variety on Mango Fruit Firmness during Storage

Table 2 Interaction Effect of Variety and Plant-based Extracts on Firmness of Mango Fruit during Storage

Varieties (V)	**Extracts (E)**	**0WAS**	**1WAS**	**2WAS**	**3WAS**	**4WAS**
Julie	*Aloe vera* gel	4.32	4.10	2.25	1.75	1.35
	Bark of *Aloe vera*	4.32	3.80	2.50	1.70	1.40
	Control	4.32	4.05	2.05	1.80	1.15
Mabrouka	*Aloe vera* gel	4.52	4.25	2.40	2.30	1.80
	Bark of *Aloe vera*	4.52	4.35	2.75	2.45	2.05
	Control	4.52	4.60	2.15	1.85	1.70
F-LSD (P≤0.05)		NS	0.106	NS	0.254	0.095
F.pr		0.860	0.001	0.163	0.004	0.025

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.1.3. Decay (%)

The effect of variety on mango fruit decay during storage showed that Julie consistently had the highest decay percentage from 1 to 4 weeks after storage (WAS). Throughout the storage period, a significant difference was observed between the two varieties, with Mabrouka showing the lowest decay percentage (Table 3). By the end of storage, Julie reached a decay percentage of 19.17. When plant-based extracts were evaluated, the untreated control group had the highest decay percentage across all time points: 5.00 (1 WAS), 11.10 (2 WAS), 15.00 (3 WAS), and 18.78 (4 WAS). Significant differences were also observed among the plant-based extract treatments.

The interaction between variety and plant-based extracts revealed that the untreated Julie control had a statistically higher decay percentage than all other treatment-variety combinations from weeks 2 to 4 after storage. At 2 WAS, untreated Julie (22.20) showed the highest decay, compared to Julie treated with Aloe vera bark (11.11), Mabrouka treated with Aloe vera bark (0.01), and all other treatments. A similar pattern appeared at 3 WAS, where the untreated control (22.20) again produced the highest decay percentage. Significant differences were observed when it was compared to Julie treated with Aloe vera gel (4.00), Julie treated with Aloe vera bark (10.00), Mabrouka treated with Aloe vera gel (0.00), Mabrouka treated with Aloe vera bark (0.01), and the Mabrouka control (0.02). By the end of the storage period, the untreated Julie control had the highest decay percentage (37.50), which was significantly different from the untreated Mabrouka control (20.00), Julie treated with Aloe vera gel (10.00), Julie treated with Aloe vera bark (10.00), Mabrouka treated with Aloe vera gel (0.00), and Mabrouka treated with Aloe vera bark (0.00) (Table 4).

Table 3 Main Effect of Variety and Plant-based Extracts on the Decay Percentage of Mango Fruits during Storage

	DECAY (%)				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	0.00	5.00	11.10	14.10	19.17
Mabrouka	0.00	0.00	0.00	3.12	6.67
F-LSD (P≤0.05)	NS	0.019	0.01	0.008	0.012
F.pr	0.00	0.007	0.002	0.001	0.002
Extracts (E)					
Aloe vera gel	0.00	2.50	0.00	3.00	5.00
Aloe vera bark	0.00	0.00	5.55	7.44	15.00
Control	0.00	5.00	11.10	15.00	18.75
F-LSD (P≤0.05)	NS	0.045	0.006	0.025	0.009
F.pr	0.00	0.02	0.03	0.001	0.008

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

Table 4 Interaction Effect of Variety and Plant-based Extracts on the Decay (%) of Mango Fruits during Storage

Variety (V)	**Extract (E)**	**0WAS**	**1WAS**	**2WAS**	**3WAS**	**4WAS**
Julie	*Aloe vera* gel	0.00	5.00	0.00	4.00	10.00
	Aloe vera bark	0.00	0.00	11.11	10.00	10.00
	Control	0.00	10.00	22.20	22.20	37.50
Mabrouka	*Aloe vera* gel	0.00	0.00	0.00	0.00	0.00
	Aloe vera bark	0.00	0.00	0.01	0.01	0.00
	Control	0.00	0.00	0.00	0.02	20.00
F-LSD (P≤0.05)		NS	NS	0.018	0.034	0.084
F.pr		0.000	0.000	0.005	0.001	0.009

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.2. Preservative Potential of *Aloe vera* gel and Bark of *Aloe vera* on the chemical characteristics of Mango Fruits during Storage

3.2.1. Total Soluble Solids (TSS)

The main effect of variety on the TSS showed that Julie consistently produced statistically higher TSS than Mabrouka across all evaluated weeks (Table 5).

At 1 WAS, fruits treated with *Aloe vera* bark had better TSS (16.55) than those treated with *Aloe vera* gel (14.90) and the untreated control (14.38). At 2WAS, however, *Aloe vera* gel (17.25) resulted in statistically higher TSS compared to *Aloe vera* bark (15.93) and the control (15.50). A Similar trend was observed at 3 WAS where *Aloe vera* gel (21.23) gave the highest TSS followed by *Aloe vera* bark (19.63) and the control (19.58). At the end of the storage period, *Aloe vera* bark (22.00) produced significantly better TSS than both *Aloe vera* gel (21.45) and the control (20.33) (Table 5).

The interaction effect between variety and plant-based extracts was also significant. Among all treatments, Julie treated with *Aloe vera* bark (22.00) yielded the highest TSS. At 2 WAS, Julie treated with *Aloe vera* gel (23.00) showed statistically higher TSS than all other variety-plant-based extract combinations. A similar pattern emerged at 3 WAS, where Julie treated *Aloe vera* gel (25.25) again outperformed the other treatments. By the end of storage, Julie treated with *Aloe vera* gel (24.70) produced statistically higher TSS than Julie treated with *Aloe vera* bark (24.00), the untreated Julie control (22.00), and all other plant-based extract treatments (Table 6).

Table 5 Main Effect of Variety and Plant-based Extracts on Total Soluble Solids (TSS) (°Brix) Content of Mango Fruits during Storage

	Total Soluble Solids (TSS) (°Brix)				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	4.32	19.33	20.17	22.55	23.57
Mabrouka	3.63	11.22	12.28	17.73	18.95
F-LSD (P≤0.05)	0.191	0.135	0.268	0.139	0.318
F.pr	0.001	0.001	0.001	0.001	0.001
Extracts (E)					
Aloe vera gel	3.97	14.90	17.25	21.23	21.45
Aloe vera bark	3.97	16.55	15.93	19.63	22.00
Control	3.56	14.38	15.50	19.58	20.33
F-LSD (P≤0.05)	NS	0.165	0.329	0.170	0.161
F.pr	0.899	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

Table 6 Interaction Effect of Variety and Plant-based Extracts on Total Soluble Solids (TSS) (°Brix) Content of Mango Fruits during Storage

Variety (V)	Extract (E)	0WAS	1WAS	2WAS	3WAS	4WAS
Julie	*Aloe vera* gel	3.60	17.90	23.00	25.25	24.70
	Aloe vera bark	3.60	22.00	18.75	21.25	24.00
	Control	3.60	18.10	18.75	21.05	22.00
Mabrouka	*Aloe vera* gel	3.56	11.90	13.10	18.20	18.20
	Aloe vera bark	3.56	11.10	12.25	20.00	20.00
	Control	3.56	10.65	11.50	18.65	18.65
F-LSD (P≤0.05)		NS	0.23	0.46	0.24	0.29
F.pr		0.999	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.2.2. pH

The main effect of variety on mango fruit pH showed that both cultivars experienced an increase in pH during storage: Julie rose from 1.71 to 4.79, and Mabrouka from 1.54 to 4.62. Throughout the storage period, Julie consistently produced significantly higher pH values than Mabrouka.

When plant-based extracts were considered, *Aloe vera* gel at 1 week after storage (WAS) gave a statistically higher pH (3.48) compared to *Aloe vera* bark (3.24) and the control (3.14). At 2 WAS, untreated fruits (control) had a significantly higher pH (4.51) than both *Aloe vera* gel (4.08) and *Aloe vera* bark (4.19). A similar trend was observed at 3 WAS, where the control again produced a significantly higher pH (5.01) compared to *Aloe vera* gel (4.90) and bark (4.89). By the end of the storage period, the control continued to show a statistically higher pH (4.89) than *Aloe vera* gel (4.50) and bark (4.72) (Table 6).

Table 7 Main Effect of Variety and Plant-based Extracts on pH of Mango Fruits during Storage

	pH				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	1.71	3.62	4.91	4.94	4.79
Mabrouka	1.54	2.95	3.60	4.93	4.62
F-LSD (P≤0.05)	0.003	0.007	0.012	0.007	0.088
F.pr	0.001	0.001	0.001	0.005	0.002
Extracts (E)					
Aloe vera gel	1.62	3.48	4.08	4.90	4.50
Aloe vera bark	1.62	3.24	4.19	4.89	4.72
Control	1.62	3.14	4.51	5.01	4.89
F-LSD (P≤0.05)	NS	0.009	0.015	0.009	0.110
F.pr	0.899	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

The interaction effect between variety and plant-based extracts was also notable. At 1 WAS, Julie treated with *Aloe vera* gel (3.94) produced a significantly better pH value than all other combinations. At 2 WAS, Julie treated with *Aloe vera* bark (5.03) yielded a significantly higher pH than the other treatments, including Mabrouka treated with *Aloe vera* gel (also 5.03). At 3 WAS, Mabrouka treated with *Aloe vera* gel recorded the highest pH, with significant differences observed among variety–extract combinations. At the end of storage, untreated Julie fruits (control) gave the highest pH value (5.23), which was statistically superior to all other treatments (Table 7).

Table 8 Interaction Effect of Variety and Plant-based Extracts on pH of Mango Fruits during Storage

Variety	Treatments	0WAS	1WAS	2WAS	3WAS	4WAS
Julie	*Aloe vera* gel	1.60	3.94	5.00	4.77	4.47
	Aloe vera bark	1.60	3.48	5.03	5.02	4.66
	Control	1.60	3.45	4.72	5.02	5.23
Mabrouka	*Aloe vera* gel	1.54	3.03	3.16	5.03	4.54
	Aloe vera bark	1.54	3.00	3.35	4.76	4.78
	Control	1.54	2.82	4.29	5.00	4.55
F-LSD (P≤0.05)		NS	0.012	0.021	0.013	0.153
F.pr		1.000	0.001	0.001	0.001	0.01

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.2.3. Titratable Acidity

The effect of variety on titratable acidity (TA) showed a clear decrease over time in both cultivars: Julie dropped from 0.67 to 0.27, while Mabrouka decreased from 1.01 to 0.32. Mabrouka consistently exhibited the highest TA throughout the observation period. At 0 weeks after storage (WAS), Mabrouka (1.02) had significantly higher TA than Julie (0.67). By 1 WAS, TA increased in both varieties; Mabrouka reached 2.45 and Julie 0.98—and the difference remained significant. At 2 WAS, Mabrouka (1.18) was again statistically higher than Julie (0.24). A similar pattern was observed at 3 WAS, with Mabrouka (0.29) significantly exceeding Julie (0.28). By the end of the storage period (4 WAS), Mabrouka (0.32) continued to show higher TA than Julie (0.27), and the difference was significant (Table 8).

Table 9 Main Effect of Variety and Plant-based Extracts on Titratable Acidity of Mango Fruits during Storage

	Titratable Acidity (%)				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	0.67	0.98	0.24	0.28	0.27
Mabrouka	1.02	2.45	1.18	0.29	0.32
F-LSD (P≤0.05)	0.007	0.037	0.01	0.007	0.003
F.pr	0.001	0.001	0.001	0.007	0.001
Extracts (E)					
Aloe vera gel	0.85	1.44	1.01	0.23	0.38
Aloe vera bark	0.85	1.57	0.79	0.35	0.23
Control	0.80	2.14	0.34	0.26	0.28
F-LSD (P≤0.05)	NS	0.045	0.012	0.008	0.003
F.pr	0.532	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

Looking at the main effect of plant-based extracts on TA, the control (2.14) at 1 WAS produced significantly higher TA than Aloe vera gel (1.44) and Aloe vera bark (1.57). At 2 WAS, Aloe vera gel (1.01) gave significantly higher TA than Aloe vera bark (0.74) and the control (0.34). By 3 WAS, Aloe vera bark (0.35) was statistically higher than Aloe vera gel (0.23) and the control (0.26). At the end of the trial (4 WAS), Aloe vera gel (0.38) produced significantly higher TA than Aloe vera bark (0.23) and the control (0.28) (Table 8).

Regarding the interaction between variety and plant-based extracts, several notable effects emerged. At 1 WAS, the Mabrouka control (2.95) differed significantly from Mabrouka treated with Aloe vera bark (2.45), Mabrouka treated with Aloe vera gel (1.96), and all other treatments. At 2 WAS, Mabrouka treated with Aloe vera gel (1.77) was significantly higher than Mabrouka treated with Aloe vera bark (1.34) and the remaining treatments. At 3 WAS, Julie treated with Aloe vera bark (0.36) produced significantly higher TA than any other extract treatment. Finally, at 4 WAS, Mabrouka treated with Aloe vera gel (0.40) was significantly different from Julie treated with Aloe vera gel (0.35) and all other treatments (Table 9).

Table 10 Interaction Effect of Variety and Plant-based Extracts on Titratable Acidity of Mango Fruits during Storage

Variety (V)	**Extract (E)**	**0WAS**	**1WAS**	**2WAS**	**3WAS**	**4WAS**
Julie	*Aloe vera* gel	0.67	0.92	0.24	0.21	0.35
	Aloe vera bark	0.67	0.69	0.24	0.36	0.19
	Control	0.67	1.34	0.25	0.25	0.26
Mabrouka	*Aloe vera* gel	0.80	1.96	1.77	0.25	0.40
	Aloe vera bark	0.80	2.45	1.34	0.35	0.26
	Control	0.80	2.95	0.44	0.26	0.31
F-LSD (P≤0.05)		NS	0.064	0.018	0.013	0.005
F.pr		0.235	0.001	0.001	0.001	0.01

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.3. Preservative Potential of *Aloe vera* gel and Bark of *Aloe vera* on the quality of Mango Fruits during Storage

3.3.1. Lycopene Content

Table 11 Main Effect of Variety and Plant-based Extracts on Lycopene (mg/100g) Content of Mango Fruits during Storage

	LYCOPENE (mg/100g)				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	0.23	0.21	0.18	0.13	0.04
Mabrouka	0.16	0.18	0.13	0.01	0.05
F-LSD (P≤0.05)	NS	0.001	0.001	0.0003	0.004
F.pr	0.125	0.001	0.001	0.001	0.012
Extracts (E)					
Aloe vera gel	0.20	0.17	0.17	0.10	0.04
Aloe vera Bark	0.20	0.12	0.13	0.09	0.08
Control	0.20	0.29	0.16	0.02	0.01
F-LSD (P≤0.05)	NS	0.001	0.001	0.0001	0.005
F.pr	0.22	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

Table 5 revealed that Julie significantly had higher Lycopene content than Mabrouka from 1WAS - 3WAS. At 4 WAS Mabrouka (0.05) produced significantly higher lycopene content than Juclie (0.04). At 1 WAS, the untreated control (0.29) had the highest lycopene content, outperforming *Aloe vera* gel (0.17) and *Aloe vera* bark (0.12). by 2 WAS, *Aloe vera* gel (0.17) was statistically superior to both the control (0.16) and *Aloe vera* bark (0.13). a similar pattern emerged at 3 WAS, where *Aloe vera* gel (0.10) again yielded significantly higher lycopene than *Aloe vera* bark (0.09) and control

(0.02). At 4 WAS, *Aloe vera* bark (0.08) became the most effective, surpassing, *Aloe vera* gel (0.040 and the control (0.01) (Table 10).

Table 11 showed that at 1 WAS, the untreated (control) Julie group (0.46) differed significantly from all other extract treatments. The same trend continued at 2 WAS: the Julie control (0.23) produced significantly higher lycopene than Julie treated with *Aloe vera* gel (0.19), Julie treated with *Aloe vera* bark (0.11), Mabrouka treated with *Aloe vera* gel (0.15), Mabrouka treated with *Aloe vera* bark (0.15), and the Mabrouka control (0.09). At 3 WAS, Julie treated with either *Aloe vera* gel (0.18) or *Aloe vera* bark (0.18) recorded the highest lycopene content. This was significantly higher than the Julie control (0.02), Mabrouka treated with *Aloe vera* gel (0.01), Mabrouka treated with *Aloe vera* bark (0.00), and the Mabrouka control (0.02). By the end of the storage period (4 WAS), Mabrouka treated with *Aloe vera* bark (0.11) yielded the highest lycopene content, which was significantly greater than Julie treated with *Aloe vera* gel (0.05), Julie treated with *Aloe vera* bark (0.06), the Julie control (0.02), Mabrouka treated with *Aloe vera* gel (0.04), and the Mabrouka control (0.01) (Table 11).

Table 12 Interaction Effect of Variety and Plant-based Extracts on Lycopene (mg/100g) Content of Mango Fruits during Storage

Variety (V)	Extract (E)	0WAS	1WAS	2WAS	3WAS	4WAS
Julie	*Aloe vera* gel	0.23	0.12	0.19	0.18	0.05
	Aloe vera bark	0.23	0.04	0.11	0.18	0.06
	Control	0.23	0.46	0.23	0.02	0.02
Mabrouka	*Aloe vera* gel	0.16	0.21	0.15	0.01	0.04
	Aloe vera bark	0.16	0.20	0.15	0.00	0.11
	Control	0.16	0.12	0.09	0.02	0.01
F-LSD (P≤0.05)		NS	0.001	0.001	0.0004	0.007
F.pr		0.321	0.001	0.001	0.001	0.001

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

3.3.2. Beta-Carotene

The effect of variety on beta-carotene content varied over time. At 1 week after storage (WAS), Julie (0.09) showed significantly higher beta-carotene levels than Mabrouka (0.06). By 2 WAS, however, Mabrouka (0.17) produced significantly more beta-carotene than Julie (0.15). A similar pattern continued at 3 WAS, with Mabrouka (0.31) again outperforming Julie (0.28) significantly. At the end of the storage period (4 WAS), Julie (0.40) had higher beta-carotene content than Mabrouka (0.30), though this difference was not statistically significant. When comparing plant-based extracts, Aloe vera gel (0.10) led to significantly higher beta-carotene than Aloe vera bark (0.07) and the control (0.06) at 1 WAS. The same trend appeared at 2 WAS, where Aloe vera gel (0.18) outperformed both the bark (0.14) and the control (0.15). At 3 WAS, Aloe vera bark (0.35) produced the highest beta-carotene, showing a significant difference compared to the gel (0.31) and the control (0.23). By the end of the experiment (4 WAS), the control (0.39) recorded the highest beta-carotene level, but no significant differences were found among the control, Aloe vera gel (0.33), and Aloe vera bark (0.33) (Table 12).

The interaction effect between variety and extract on beta-carotene also revealed distinct patterns. At 1 WAS, the Julie control (0.11) and Julie treated with Aloe vera gel (0.11) produced the highest beta-carotene levels, significantly outperforming Julie treated with Aloe vera bark (0.06) and the Mabrouka control (0.02). At 2 WAS, Julie treated with Aloe vera gel (0.22) yielded significantly more beta-carotene than Julie treated with Aloe vera bark (0.12), the Julie control (0.11), Mabrouka treated with Aloe vera gel (0.14), Mabrouka treated with Aloe vera bark (0.17), and the Mabrouka control (0.20). At 3 WAS, Julie treated with Aloe vera bark (0.44) showed a significant difference compared to Julie treated with Aloe vera gel (0.25), the Julie control (0.17), Mabrouka treated with Aloe vera gel (0.36), Mabrouka treated with Aloe vera bark (0.27), and the Mabrouka control (0.28). By 4 WAS, the Julie control (0.47) recorded the highest beta-carotene among all treatments, though no significant differences were observed (Table 13).

Table 13 Main Effect of Variety and Plant-based Extracts on the Beta-Carotene Content of Mango Fruits during Storage

	BETA-CAROTENE (mg/100g) CONTENT				
Varieties (V)	0 WAS	1WAS	2WAS	3WAS	4WAS
Julie	0.02	0.09	0.15	0.28	0.40
Mabrouka	0.03	0.06	0.17	0.31	0.30
F-LSD (P≤0.05)	NS	0.0001	0.001	0.003	NS
F.pr	0.123	0.001	0.001	0.001	0.355
Extracts (E)					
Aloe vera gel	0.03	0.10	0.18	0.31	0.33
Aloe vera bark	0.03	0.07	0.14	0.35	0.33
Control	0.03	0.06	0.15	0.23	0.39
F-LSD (P≤0.05)	NS	0.0001	0.001	0.004	NS
F.pr	0.074	0.001	0.001	0.001	0.858

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

Table 14 Interaction Effect of Variety and Plant-based Extracts on the Beta-Carotene Content of Mango Fruits during Storage

Variety (V)	**Extract (T)**	**0WAS**	**1WAS**	**2WAS**	**3WAS**	**4WAS**
Julie	*Aloe vera* gel	0.03	0.11	0.22	0.25	0.32
	Aloe vera bark	0.03	0.07	0.12	0.44	0.40
	Control	0.03	0.11	0.11	0.17	0.47
Mabrouka	*Aloe vera* gel	0.02	0.10	0.14	0.36	0.34
	Aloe vera bark	0.02	0.06	0.17	0.27	0.26
	Control	0.02	0.02	0.20	0.28	0.30
F-LSD (P≤0.05)		NS	0.0001	0.0001	0.005	NS
F.pr		0.060	0.001	0.001	0.001	0.715

WAS = Weeks after storage; F.pr = Probability value; NS = Not Significant

4. Discussion

The efficacy of *Aloe vera* bark and gel extracts on the postharvest quality of mango fruits were investigated. The postharvest quality parameters assessed included weight, firmness, decay, pH, total soluble solids (TSS), titratable acidity (TA), lycopene, and beta-carotene. This study found that mango fruit weight decreased over the storage period. However, fruits treated with Aloe vera gel or bark extracts showed the lowest postharvest weight loss compared to untreated fruits. This reduction is likely due to the formation of a protective film on the fruit surface, which reduces evapotranspiration and respiration rates (Shrestha *et al*., 2018). These findings align with earlier research by Iorliam *et al.* (2025); Kudrat-Khuda *et al.* (2024); Hassan (2022); Passanet *et al.* (2019); and Ochiki *et al.* (2015), all of whom reported that extracts from plant-based sources such propolis, garlic, neem, ginger, and *Aloe vera* gel reduce postharvest weight loss in mangoes. Similar results have also been reported on other fruits: Garcia *et al.* (2013), Liamngee *et al.* (2019), Liamngee *et al.* (2018), and Hosea *et al.* (2017) observed weight reduction in tomatoes coated with neem powder and Aloe vera gel. Notably, mango fruits coated with Aloe vera gel extract had lower weight loss than those coated with bark extract, possibly due to the gel's higher viscosity.

Fruit firmness is a key parameter for evaluating fruit maturity. The results showed a gradual decline in firmness during storage for both treated and control fruits. However, the control fruits experienced the greatest loss in firmness. The coatings helped stabilize mango firmness, slowing the ripening process and thereby extending shelf life. Reduced respiration and lower water loss are likely responsible for maintaining firmness, as they minimize cell turgor loss and slow down cell-wall-degrading enzymes such as polygalacturonase, pectic galactanase, and beta-galactosidase during storage (Passanet *et al.,* 2019). The waxy nature of *Aloe vera* extract provides an advantage over untreated fruits, enabling rapid formation of a strong film that reduces metabolic rate and delays enzymatic breakdown of the cell wall, thus prolonging fruit firmness.

Postharvest decay increased with storage time across all treatments. Nevertheless, mangoes treated with either *Aloe vera* bark or gel exhibited less decay than untreated fruits. Decay and desiccation are the two main causes of reduced commercial and marketable shelf life in fruits, often resulting from postharvest diseases and physiological disorders (Liamngee *et al.,* 2019). Coating fruits with *Aloe vera* extracts helped protect against fungal attack. Phytochemical screening of these extracts revealed bioactive compounds such as tannins, saponins, flavonoids, glycosides, and anthraquinones, which help inhibit microbial invasion. These phytochemicals are thought to work by suppressing or inhibiting microorganism growth (Garcia *et al.,* 2013). The study also showed that both *Aloe vera* bark and gel extracts helped maintain fruit marketability throughout the storage period, likely by preventing fungal decay that would otherwise reduce market value.

Total soluble solids (TSS) increased in mango fruits as storage time advanced. Neupane *et al*. (2024) noted that increased activity of starch-hydrolyzing enzymes may explain the rise in TSS during ripening. This study found significantly higher TSS in treated mangoes than in untreated ones. This may be due to the film formed by *Aloe vera* gel and bark extracts, which reduces transpiration and delays ripening. In contrast, untreated fruits lacked a barrier to gas exchange, accelerating ripening. These observations are consistent with reports from Gupta and Jain (2014), and Shrestha *et al.* (2018), all of whom documented higher TSS in treated mangoes compared to untreated controls.

A rising trend in pH was observed during storage, probably due to the oxidation of organic acids. This pattern has been noted by Shrestha *et al.* (2018), Ochiki *et al.* (2015), Passanet *et al.* (2019), and Gupta and Jain (2014) in mangoes. However, mangoes coated with *Aloe vera* bark or gel extracts maintained a lower pH than untreated fruits. Mangoes contain organic acids such as citric, malic, and tartaric acids, which break down over time due to oxygen consumption, causing pH to rise. The film formed by *Aloe vera* extracts reduces respiration rate, thereby slowing the pH increase compared to untreated fruits with higher respiration rates (Neupane *et al.,* 2024). Additionally, titratable acidity (TA) decreased during storage, with some variation among treatments. This decline in acidity as fruits mature may result from the breakdown of starch into sugars, lowering the acid percentage (Neupane *et al.,* 2024). Nordey *et al.* (2016) explained that climacteric respiration may contribute to the decline in TA during mango ripening, as organic acids serve as substrates for climacteric respiration.

Treated fruits also recorded higher beta-carotene and lycopene levels than untreated fruits. The bio-preservative layer formed on treated fruits helps maintain lower fruit temperature, thereby slowing respiration. Beta-carotene content in mangoes increased notably with storage duration, likely due to chlorophyll breakdown and a rise in carotenoid levels facilitated by the chlorophyllase enzyme (Xin *et al.,* 2025). This increase in carotenoids during ripening is associated with the climacteric rise in respiration and ethylene production.

5. Conclusion

The results of this research demonstrate that both *Aloe vera* gel and *Aloe vera* bark extracts can improve the physical properties of mango fruits during storage. These extracts also extend shelf life and help maintain the physicochemical quality of the fruits. However, the mango variety itself played a significant role in determining the extent of these changes.

As storage duration increased, postharvest weight change (PWC) and titratable acidity (TA) decreased across all treatments. Fruit firmness also declined over time, with statistically significant differences observed between samples during the storage period. Total soluble solids remained relatively stable, showing little variation between the two extracts. That said, the Julie variety consistently showed higher total soluble solids than the Mabrouka variety, regardless of whether the fruits were treated or untreated.

Changes in pH values were erratic and appeared to depend more on the mango variety than on the type of extract applied. Additionally, decay percentage increased significantly over the storage period, while marketability declined. Treated fruits consistently showed lower decay percentages and, as a result, higher marketability compared to untreated fruits. In conclusion, these plant extracts offer not only environmentally friendly, easy-to-produce, and easy-to-apply formulations, but also a safe alternative for consumers. They provide an effective means of maintaining postharvest physiology and managing crop quality.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist

Authors Contribution

Conceptualization: MOA and MOO, Methodology: MOA, TG and AAM, Investigation: MOA, TG, BB and AAM, Writing Original Draft Preparation: MOA, TG BB, AAM and MOO, Writing Review and Editing: MOA, TG BB, AAM and MOO, Supervision: MOO. All authors read and agreed to the published version of the manuscript.

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