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Effect of plant extracts and chemical treatments under MAP on post-harvest quality of banana

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Abstract

This study was conducted to assess the effect of plant extracts and chemical treatments under modified atmosphere packaging on the postharvest quality and shelf life of 'Grand Naine' banana. This experiment was conducted in the laboratory of Department of Horticulture of AFU, Rampur from August to September 2024. This experiment was laid out in Completely Randomized Design (CRD) with eight treatments, each replicated thrice. The treatments involved in this experiment were Low Density Polyethylene (LDPE), LDPE + 20% garlic extract, LDPE + 20% onion extract, LDPE + 20% ginger extract, LDPE + 20% neem extract, LDPE + 4% $CaCl_2$, LDPE + 1% $KMnO_4$ and control. From this experiment, it was found that LDPE + 1% $KMnO_4$ treated fruits had the lowest physiological loss in weight (8.42%), highest vitamin C content (11.83 mg/100 g), reduced softening with maximum firmness (3.47kg/cm^2) and the longest shelf life of 26.5 days. Similarly, fruits treated with LDPE + 4% $CaCl_2$ had the lowest color score (4.67) on 15th day of storage. Among plant extracts, LDPE + 20% neem extract was proved effective in minimizing physiological loss in weight (13.33%), reducing changes in total soluble solids (TSS) and titratable acidity (TA) and preserving fruit firmness (3.13 kg/cm^2). Based on the findings, it can be concluded that modified atmosphere packaging in combination with 1% $KMnO_4$ can effectively delay the onset of climacteric phase, delay ethylene synthesis and increase the shelf life of banana.

1. INTRODUCTION

Banana (*Musa spp.*) is an important fruit crop grown in tropical and sub-tropical regions of over 130 countries globally (Belay, 2022). It is a rich source of carbohydrates, dietary fiber, potassium, vitamin B_6, vitamin C and antioxidants (Siddiq et al., 2020). However, banana fruits are highly perishable and undergo rapid physiological and biochemical changes after harvest, including increased respiration, rapid ethylene synthesis and microbial decay. Postharvest loss poses a major threat to food security and global hunger. Globally, postharvest loss in fruits and vegetables can reach up to 50% at different stages of value chain (Gustavsson et al., 2011). Postharvest loss of horticultural crops accounts nearly one third of total production in Nepal (Gautam et al., 2019). Therefore, effective postharvest management strategies are essential to maintain fruit quality and reduce losses.

Chemical treatments, such as potassium permanganate ($KMnO_4$) and calcium chloride ($CaCl_2$), have been widely used to suppress ethylene activities, reduce respiration rates and maintain fruit firmness. $KMnO_4$ acts as an ethylene oxidizing agent and slows down ripening and senescence processes (Dhakal et al., 2021). Calcium strengthens the middle lamella by forming calcium pectate, which maintains fruit firmness and reduce the moisture loss (Tzortzakis, 2010). In addition, plant-derived extracts used as postharvest treatments have gained significant attention due to their antimicrobial and antioxidant properties (Chen et al., 2025).

Modified Atmosphere Packaging (MAP) alters the gaseous environment surrounding the product by regulating the permeability of CO_2 and O_2 through packaging films, thereby reducing respiration rate, moisture loss, and extending shelf life (Priyadarshi et al., 2020). However, comprehensive studies comparing the effectiveness of plant extracts and chemical treatments under modified atmosphere packaging are limited. This study aims to evaluate the effect of selected plant extracts and chemical treatments under modified atmosphere packaging on the postharvest quality of banana.

2. MATERIALS AND METHODS

2.1 Experimental site and plant material

The experiment was conducted in the Horticulture Laboratory of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal during August–September 2024. Banana fruits of the cultivar ‘Grand Naine (G-9)’, one of the most widely cultivated cultivars in Nepal due to its high productivity and relative tolerance to diseases such as Panama wilt, were

collected from Bhantana Banana Farm, Tandi, Chitwan. The seedlings of the banana (Grand Naine) was taken from the nursery owner of banana from Abhiyan Sahakari Sastha, Pvt. Ltd. which is close to the University area.

2.2 Fruit harvesting and sample preparation

Bunches at full physiological maturity were randomly harvested from ten plants and de-handed. To ensure uniformity, the topmost and bottommost hands were discarded and blemish-free fruits of uniform size were selected. The fruits were washed with tap water to remove latex and adhering dirt, sanitized with 500 ppm sodium hypochlorite to reduce microbial contamination, and air-dried at room temperature before treatment application.

2.3 Treatment details

T_1: Control (distilled water)

T_2: Low Density Polyethylene bags (LDPE)

T_3: LDPE + 20% garlic extract

T_4: LDPE + 20% onion extract

T_5: LDPE + 20% ginger extract

T_6: LDPE + 20% neem extract

T_7: LDPE + 4% calcium chloride ($CaCl_2$)

T_8: LDPE + 1% potassium permanganate ($KMnO_4$)

2.4 Treatment preparation

Modified atmosphere was created using Low Density Polyethylene (LDPE) bags of 40 µm thickness with 4 macro perforations and many micro-perforations. $KMnO_4$ of 1% was prepared by dissolving one gram of $KMnO_4$ in 100 ml water. Cotton soaked in $KMnO_4$ solution was packed into small sachets placed inside the LDPE bags along with banana fruits. For $CaCl_2$ treatment, a 4% solution was prepared by dissolving 4.08 g $CaCl_2$ (98% purity) in distilled water and adjusting the volume to 100 ml. Plant extracts were prepared by grinding 1 kg of fresh plant material with 1 L of distilled water (1:1 w/v), followed by filtration through muslin cloth to extract juice, which was regarded as the 100% concentrated extract. It was then diluted to make a 20% solution and fruits were dipped in the respective solutions for 5 minutes and air-dried before packaging.

2.5 Experimental design

The experiment was laid out in a Completely Randomized Design (CRD) with eight treatments and three replications. Each replication consisted of twelve fingers, of which five were used for non-destructive observations and remaining seven for destructive analyses. Fruits were stored under ambient laboratory conditions with an average temperature of 28.5°C and relative humidity of approximately 85%.

2.6 Parameters observed

Physiological loss in weight (PLW) was measured by using a digital balance and expressed as percentage. Peel color of fruits was categorized using a standardized peel color chart described by Acedo and Bautista (1991). The chart classifies peel color development ranging from 1 to 8, from fully green to predominantly yellow, with intermediate stages showing gradual yellowing and the appearance of brown flecks. Fruit firmness was determined using handheld mechanical penetrometer and expressed in kg/cm². Total soluble solids (TSS), titratable acidity (TA) and vitamin C content were analyzed from the destructive samples in the lab. Shelf life was calculated as number of days until more than 50% of fruits

in a treatment become unacceptable due to over-softening, browning or decay. Data were subjected to analysis of variance (ANOVA) using R-Studio software. Mean separation was performed using Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

3. RESULTS AND DISCUSSIONS

3.1 Physiological loss in weight (PLW)

The detailed effect of different treatments on physiological loss in weight of G-9 banana is illustrated in Table 1. Physiological loss in weight increased gradually with storage duration. At 3 days after storage (DAS), the minimum PLW (0.68%) was recorded in fruits treated with LDPE+ 4% $CaCl_2$, which was statistically similar to all treatments except LDPE alone and control. At 6 DAS, lower PLW (1.27%) was found with LDPE+ 20% ginger extract, which was statistically similar to all other treatments except LDPE alone and control. At 9, 12 and 15 DAS fruits treated with LDPE+ 1% $KMnO_4$ recorded significantly lower PLW of 2.26%, 5.49% and 8.42% respectively. Data for the control were not recorded at 15 DAS due to complete spoilage. Fruits packed in LDPE had consistently lower PLW than control, which can be attributed to reduced moisture loss and lower respiration rates under modified atmosphere (Yogi et al., 2023). Sammi and Masud (2009) reported that $KMnO_4$ oxidizes ethylene into CO_2 and H_2O, thereby creating atmosphere with high CO_2 and relative humidity inside the package, which reduces transpiration and ultimately minimizes weight loss. Similarly, plant extracts such as ginger and neem also reduced PLW significantly, potentially due to their bioactive compounds inhibiting microbial growth and slowing metabolic water loss (Dahiya & Singh, 2018).

3.2 Change in peel color

The detailed effect of different treatments on peel color change of G-9 banana during storage is presented in Table 2. At **3 days after storage (DAS),** no significant differences among the treatments were observed in peel color development, indicating that most of fruits remained at green stage. However, as storage progressed, the peel color of banana fruits increased gradually, indicating progressive ripening from the green stage to yellow. The treatments significantly influenced peel color development at later observation days ($p < 0.001$). At 6 DAS, fruits treated with LDPE+ 4% $CaCl_2$, LDPE + 20% neem extract, and LDPE+ 20% garlic extract recorded the lowest color scores, indicating slower ripening, whereas the control fruits showed the highest color score (3.33), indicating faster color change. At 9 and 12 DAS, fruits treated with LDPE+ 4% $CaCl_2$ maintained significantly lower color scores (2.00 and 3.33, respectively) and were statistically at par with LDPE+ 20% neem extract, LDPE+ 20% ginger extract, and LDPE+ 1% $KMnO_4$ treatments. By 15 DAS, control fruits were discarded due to complete peel blackening, while LDPE+ 4% $CaCl_2$ treated fruits exhibited the lowest color score (4.67) and were statistically similar to LDPE+ 1% $KMnO_4$ treatment. This aligns with Chandrakar and Patel (2022), who reported that $CaCl_2$ treatment delays senescence, slows metabolic activity, and reduces chlorophyll degradation. $KMnO_4$ treated fruits also exhibited slower color change, likely due to its ethylene-scavenging properties which delay climacteric ethylene peak responsible for chlorophyll breakdown (Rahman et al., 2026).

3.3 Firmness and Pulp peel ratio

The effect of different treatments on firmness and pulp peel ratio of G-9 banana is well illustrated in Table 3. Fruit firmness decreased progressively during storage, indicating gradual ripening and softening of banana fruits. At 3 DAS, no significant differences in firmness were observed among treatments **($p > 0.05$)**. However, from 6 DAS onwards, significant differences were recorded ($p < 0.001$). Fruits treated with LDPE+ 4% $CaCl_2$ maintained the highest firmness throughout the storage period, with values of 5.54, 5.03, 4.73, and 3.87 kg/cm² at 6, 9, 12, and 15 DAS, respectively, which were statistically at par with LDPE+ 1% $KMnO_4$. In contrast, control fruits exhibited significantly lower firmness, indicating faster softening during

storage due to elevated activity of cell wall degrading enzymes. LDPE+ 4% $CaCl_2$ treated fruits maintained the highest firmness throughout storage period, likely due to the ability of calcium to form ionic bridges with pectin substances, strengthening the middle lamella and reducing pectin degradation (Minh, 2021). LDPE + 1% $KMnO_4$ also effectively preserved firmness, consistent with its ethylene oxidizing activity, which delays ripening and pectic hydrolysis (Sarkar et al., 2017).

Pulp-to-peel ratio increased gradually during storage as ripening progressed. At **3 DAS,** the pulp-to-peel ratio ranged from **1.29 to 1.39,** and**no significant differences among treatments were observed (p > 0.05).** However, from **6 DAS onwards,** significant differences among treatments were recorded **(p < 0.001).** Fruits treated with LDPE+ 1% $KMnO_4$ showed the lowest pulp-to-peel ratio at 6, 9, 12, and 15 DAS (1.36, 1.44, 1.80, and 2.16, respectively), indicating delayed ripening. In contrast, control treatments recorded higher ratios at 6, 9 and 12 DAS (1.93, 3.17 and 4.33, respectively), suggesting faster ripening and pulp development. Sarkar et al. (2017) reported lower pulp to peel ratio in $KMnO_4$ treated fruits may be attributed to delay ripening due to ethylene oxidation during storage, which slows metabolic activities, including the transfer of moisture from peel to pulp.

3.4 Total soluble solids and Titratable Acidity

The detailed result of effect of different treatments on TSS and TA of banana is expressed in Table 4. Total soluble solids (TSS) increased progressively during storage, reflecting the advancement of ripening in the fruits. No significant differences among treatments were observed at 3 DAS. However, from 6 DAS onwards, significant variations were recorded ($p < 0.001$). At 6 DAS, the highest TSS was observed in control fruits (9.93 °Brix), whereas the lowest values were recorded in fruits treated with LDPE+ 20% neem extract (6.40 °Brix), which was statistically at par with LDPE+ 20% ginger extract, LDPE+ 1% $KMnO_4$, and LDPE+ 4% $CaCl_2$. At 9 and 12 DAS, control fruits continued to exhibit significantly higher TSS values (16.64 and 21.87 °Brix, respectively), indicating faster ripening, while LDPE+ 1% $KMnO_4$ treated fruits maintained the lowest TSS values (7.90 and 10.80 °Brix). At 15 DAS, the highest TSS was recorded in fruits stored in LDPE alone (18.70 °Brix), whereas LDPE+ 1% $KMnO_4$ treated fruits maintained the lowest TSS (12.90 °Brix). Sarkar et al. (2017) also found that combination of LDPE packaging and $KMnO_4$ treatment delays ethylene production. $KMnO_4$ delays respiration and the conversion of starch into sugar, while LDPE packaging reduces the rate of starch hydrolysis (Kudachikar et al., 2011).

Titratable acidity (TA) did not differ significantly among treatments at 3 DAS. In control fruits, TA increased up to 9 DAS (0.65%) and declined thereafter. In contrast, fruits treated with LDPE and plant extract combinations generally reached peak acidity at 12 DAS. Notably, fruits treated with LDPE+ 1% $KMnO_4$ maintained relatively stable acidity throughout the storage period and did not show a decline up to 15 DAS (0.62%), indicating slower metabolic changes and delayed ripening. The acidity of the fruits generally increases until the occurrence of rapid starch hydrolysis; thereafter, acidity declines due to utilization of organic acids in respiration, conversion into sugars and get broken down into simpler volatile compounds contributing to fruit flavor and aroma (Famiani et al., 2015). The delayed peak acidity in LDPE+ 1% $KMnO_4$ treated fruits is likely due to the modified atmosphere slowing metabolic activity and delayed acid producing process. The obtained results are in agreement with the studies of Zewter et al. (2012).

3.5 Shelf life and Vitamin C

The effect of different treatments on shelf life and vitamin C content of G-9 banana is presented in Table 5. The highest shelf life was observed in fruits treated with LDPE+ 1% $KMnO_4$ (26.5 days), followed by fruits treated with LDPE+ 20% garlic extract (22.5 days), LDPE+ 4% $CaCl_2$ (22 days) and LDPE+ 20% neem extract (21.5 days) which were statistically at par with each other. In contrast, the control recorded the shortest shelf life (13.67 days) which was significantly lower than other treatments. The prolonged shelf life in LDPE packed fruits may be due to elevated carbon dioxide levels and reduced

oxygen levels which postpone the climacteric rise (Mendoza et al., 2016). Garlic and neem extract also contributed to shelf life extension, likely due to their antimicrobial and antioxidant properties, which reduce oxidative stress and microbial decay (Wendimu et al., 2022). The extended shelf life was attributed to moisture conservation by polyethylene packaging, while $KMnO_4$ reduced ethylene concentration and delayed climacteric rise (Zewter et al., 2012).

Vitamin C content did not differ significantly among treatments at 3 and 6 DAS. From 9 DAS onwards, LDPE+ 1% $KMnO_4$ treated fruits maintained significantly higher vitamin C levels (13.07, 12.55, and 11.83 mg 100 g^{-1} at 9, 12, and 15 DAS, respectively). In contrast, control showed a rapid decline in vitamin C content, dropping to 10.39 mg 100 g^{-1} by 9 DAS and further to 8.50 mg 100 g^{-1} by 12 DAS. Fruits packed in LDPE and treated with 1% $KMnO_4$ retained significantly higher vitamin C content, likely due to delayed ripening and reduced oxidative stress (Tran, 2024).

4. CONCLUSION

This research aimed to enhance the postharvest quality and prolong the shelf life of banana by applying plant extracts and chemical treatments under modified atmospheric conditions. The use of MAP combined with plant extracts and chemicals significantly improved the postharvest quality of banana. LDPE + 1% $KMnO_4$ was found effective in slowing down ripening, reducing weight loss, delaying changes in TSS and TA and prolonging shelf life. Among plant extracts, neem extract was found effective in vitamin C retention, delaying changes in TSS and TA and maintaining firmness of fruit. These findings indicate that the combination of plant extracts or chemicals with modified atmosphere packaging can effectively reduce postharvest deterioration in banana.

Declarations

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AUTHOR'S CONTRIBUTIONS

Credit: **Gaurav Bhatt:** Conceptualization, funding acquisition and resources management, Methodology and design of experiment, Lab analysis works, Data analysis, Writing-original draft, Writing, reviewing and editing. **Hom Nath Giri:** Conceptualization, Investigation, methodology and design of experiment, Monitoring and supervision, Funding acquisition, Writing-reviewing and editing. **Arjun Kumar Shrestha:** Reviewing and editing, Monitoring and inspection. **Arjun Subedi:** Reviewing and editing, Monitoring and inspection.

DECLEARATION OF FUNDING

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HUMAN ETHICS DECLEARATION

There was no participation of human beings for the completion of this research.

CONSENT TO PUBLISH DECLARARTION

The collection of the plants and plants parts used in our study complied with local and national guidelines which were followed. The plant materials was obtained from a private farmland nearby the university premises which was permitted by the university to conduct the research.

TYPE OF THE TRIAL

This is not a clinical trial.

ETHICS AND CONSENT TO PARTICIPATE

Not applicable.

DISCLOSURE STATEMENT

The authors have no conflicts of interest regarding the publication of this article.

DATA AVAILABILITY STATEMENT

Data related to this study is available from the principal investigator and corresponding author upon reasonable request.

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Tables

Table 1. Effect of plant extracts and chemical treatments under modified atmosphere storage on physiological loss in weight of G-9 banana

Treatments	Physiological loss in weight (%)				
	3 DAS	6 DAS	9 DAS	12 DAS	15 DAS
T_1:	8.68^{a}(2.94)	11.68^{a}(3.41)	15.79^{a}(3.96)	25.80^{a}(5.07)	-
T_2:	0.77^{b}(1.39)	1.32^{b}(2.15)	7.37^{b}(2.70)	13.60^{b}(3.68)	21.43^{a}(4.62)
T_3:	0.75^{c}(0.85)	1.80^{c}(1.32)	3.35^{c}(1.82)	8.07^{c}(2.83)	18.07^{b}(4.25)
T_4:	0.70^{c}(0.83)	1.40^{c}(1.18)	2.51^{cd}(1.57)	7.21^{cd}(2.67)	17.97^{b}(4.23)
T_5:	0.74^{c}(0.85)	1.27^{c}(1.12)	2.88^{cd}(1.69)	7.03^{cd}(2.67)	16.50^{b}(4.06)
T_6:	0.90^{c}(0.92)	1.94^{c}(1.16)	2.74^{cd}(1.65)	6.57^{cd}(2.55)	13.33^{c}(3.64)
T_7:	0.68^{c}(0.82)	1.66^{c}(1.28)	2.93^{cd}(1.70)	7.10^{cd}(2.65)	11.97^{c}(3.45)
T_8:	0.73^{c}(0.85)	1.33^{c}(1.15)	2.26^{d}(1.50)	5.49^{d}(2.33)	8.42^{d}(2.89)
SEm (±)	0.02	0.07	0.09	0.11	0.07
$LSD_{0.05}$	0.21	0.23	0.28	0.33	0.22
P value	***	***	***	***	***
CV, %	10.55	8.30	8.02	6.34	3.84
Grand mean	1.89	3.14	2.07	3.06	3.39

T_1: Control, T_2: Low Density Polyethylene bags (LDPE), T_3: LDPE+ 20% garlic extract, T_4: LDPE+ 20% onion extract, T_5: LDPE+ 20% ginger extract, T_6: LDPE+ 20% neem extract, T_7: LDPE+ 4% CaCl2 and T_8: LDPE+ 1% $KMnO_4$

Note: Means with same letter in column are not significantly different at p= 0.05 by DMRT. *** indicates highly significant at p<0.001, SEm= Standard error of mean, LSD= Least significant difference, CV= Coefficient of Variation, and DAS= Days after storage [Statistical tests were performed on square-root transformed data to meet assumptions, Figures in parentheses are transformed (square root) values]

Table 2. Effect of plant extracts and chemical treatments under modified atmosphere storage on change of peel color of G-9 banana

Treatment	Color score			
	6 DAS	9 DAS	12 DAS	15 DAS
T_1:	3.33^{a}(1.82)	6.33^{a}(2.50)	7.33^{a}(2.50)	-
T_2:	2.00^{b}(1.41)	3.00^{bcd}(1.73)	6.00^{bcd}(1.73)	6.67^{a}(2.44)
T_3:	1.00^{c}(1.00)	3.33^{bc}(1.82)	5.33^{bc}(1.82)	6.00^{ab}(2.30)
T_4:	1.67^{bc}(1.27)	4.00^{b}(1.98)	5.67^{b}(1.99)	6.67^{a}(2.37)
T_5:	1.33^{bc}(1.13)	2.67^{cd}(1.62)	5.33^{cd}(1.62)	6.33^{ab}(2.30)
T_6:	1.00^{c}(1.00)	2.33^{cd}(1.52)	4.33^{cd}(1.52)	6.33^{bc}(2.07)
T_7:	1.00^{c}(1.00)	2.00^{d}(1.41)	3.33^{d}(1.41)	4.67^{d}(1.82)
T_8:	1.33^{bc}(1.13)	2.33^{cd}(1.52)	3.67^{cd}(1.52)	5.33^{cd}(1.91)
SEm (±)	0.09	0.10	0.10	0.07
$LSD_{0.05}$	0.27	0.30	0.30	0.22
P value	***	***	***	***
CV, %	12.77	9.89	9.89	5.80
Grand mean	1.58	1.76	1.77	2.17

T_1: Control, T_2: Low Density Polyethylene bags (LDPE), T_3: LDPE+ 20% garlic extract, T_4: LDPE+ 20% onion extract, T_5: LDPE+ 20% ginger extract, T_6: LDPE+ 20% neem extract, T_7: LDPE+ 4% CaCl2 and T_8: LDPE+ 1% $KMnO_4$

Note: Means with same letter in column are not significantly different at p= 0.05 by DMRT. *** indicates highly significant at p<0.001, SEm= Standard error of mean, LSD= Least significant difference, CV= Coefficient of Variation, and DAS= Days after storage [Statistical tests were performed on square-root transformed data to meet assumptions, Figures in parentheses are transformed (square root) values]

Table 3. Effect of plant extracts and chemical treatments under modified atmosphere storage on firmness and pulp peel ratio of G-9 banana

Treatment	3 DAS		6 DAS		9 DAS		12 DAS		15 DAS	
	Firmness (kg/cm^2)	Pulp peel ratio	Firmness (kg/cm^2)	Pulp peel ratio	Firmness (kg/cm^2)	Pulp peel ratio	Firmness (kg/cm^2)	Pulp peel ratio	Firmness (kg/cm^2)	Pulp peel ratio
T1	5.63	1.38	4.37^{d}	1.93^{a}	2.63^{e}	3.17^{a}	1.70^{d}	4.33^{a}	-	-
T2	5.73	1.31	5.23^{ab}	1.87^{a}	4.20^{cd}	2.66^{ab}	3.10^{c}	3.13^{b}	1.73^{d}	3.54^{a}
T3	5.57	1.39	4.78^{c}	1.48^{b}	4.23^{cd}	1.62^{de}	3.27^{c}	2.02^{f}	1.87^{d}	2.47^{e}
T4	5.77	1.35	5.07^{b}	1.81^{a}	3.90^{d}	2.40^{bc}	3.27^{c}	2.80^{c}	1.13^{e}	3.10^{b}
T5	5.77	1.34	5.30^{ab}	1.59^{b}	4.50^{bc}	2.01^{cd}	3.20^{c}	2.57^{d}	2.40^{c}	2.91^{c}
T6	5.67	1.34	5.33^{ab}	1.47^{bc}	4.63^{b}	1.99^{cde}	4.27^{b}	2.40^{e}	3.13^{b}	2.63^{d}
T7	5.87	1.29	5.54^{a}	1.57^{b}	5.03^{a}	1.85^{cde}	4.73^{a}	2.09^{f}	3.87^{a}	2.42^{e}
T8	5.83	1.33	5.40^{a}	1.36^{c}	4.83^{ab}	1.44^{e}	4.50^{ab}	1.80^{g}	3.47^{ab}	2.16^{f}
SEm (±)	0.05	0.04	0.1	0.03	0.11	0.04	0.08	0.03	0.13	0.04
$LSD_{0.05}$	0.16	0.05	0.30	0.06	0.35	0.05	0.25	0.07	0.40	0.05
P value	ns	ns	***	***	***	***	***	***	***	***
CV, %	1.71	5.53	3.37	3.87	4.75	13.95	4.20	2.84	9.14	2.95
Grand mean	5.71	1.33	5.12	1.6	4.24	2.14	3.50	2.63	2.51	2.74

T_1: Control, T_2: Low Density Polyethylene bags (LDPE), T_3: LDPE+ 20% garlic extract, T_4: LDPE+ 20% onion extract, T_5: LDPE+ 20% ginger extract, T_6: LDPE+ 20% neem extract, T_7: LDPE+ 4% CaCl2 and T_8: LDPE+ 1% $KMnO_4$

Note: Means with same letter in column are not significantly different at p= 0.05 by DMRT. *** indicates highly significant at p<0.001 and ns: not significantly different at p>0.05, SEm= Standard error of mean, LSD= Least significant difference, CV= Coefficient of Variation, and DAS= Days after storage

Table 4. Effect of plant extracts and chemical treatments under modified atmosphere storage on total soluble solids (TSS) and Titratable acidity (TA) of G-9 banana

Treatment	3 DAS		6 DAS		9 DAS		12 DAS		15 DAS	
	TSS	TA	TSS	TA	TSS	TA	TSS	TA	TSS	TA
T1	5.71	0.33	9.93^{a}	0.45^{a}	16.64^{a}	0.65^{a}	21.87^{a}	0.60^{c}	-	-
T2	5.28	0.31	8.40^{b}	0.39^{bcd}	11.50^{b}	0.49^{bc}	15.83^{b}	0.66^{ab}	18.70^{a}	0.62^{b}
T3	5.20	0.32	7.90^{b}	0.42^{ab}	9.37^{cd}	0.5^{b}	13.90^{cd}	0.68^{ab}	16.60^{b}	0.65^{a}
T4	5.13	0.31	8.00^{b}	0.41^{bc}	9.90^{c}	0.50^{bc}	14.20^{c}	0.70^{a}	18.10^{a}	0.61^{b}
T5	5.40	0.32	6.63^{c}	0.38^{cd}	9.10^{d}	0.46^{cd}	13.50^{cd}	0.65^{b}	16.20^{b}	0.59^{c}
T6	5.47	0.33	6.40^{c}	0.39^{bcd}	8.90^{d}	0.48^{bc}	13.10^{d}	0.66^{ab}	15.00^{c}	0.62^{b}
T7	5.32	0.31	6.80^{c}	0.38^{cd}	9.40^{cd}	0.50^{bc}	14.10^{c}	0.69^{ab}	17.00^{b}	0.63^{ab}
T8	5.38	0.30	6.40^{c}	0.34^{e}	7.90^{e}	0.41^{d}	10.80^{e}	0.54^{d}	12.90^{d}	0.62^{b}
SEm (±)	0.24	0.02	0.23	0.01	0.19	0.02	0.38	0.01	0.35	0.008
$LSD_{0.05}$	0.72	0.04	0.69	0.03	0.58	0.06	0.76	0.04	1.08	0.02
P value	Ns	ns	***	***	***	***	***	***	***	*
CV, %	7.77	9.83	5.31	4.55	3.29	6.91	3.01	3.59	3.78	2.33
Grand mean	5.36	0.31	7.55	0.39	10.33	0.50	14.66	0.64	16.35	0.62

T_1: Control, T_2: Low Density Polyethylene bags (LDPE), T_3: LDPE+ 20% garlic extract, T_4: LDPE+ 20% onion extract, T_5: LDPE+ 20% ginger extract, T_6: LDPE+ 20% neem extract, T_7: LDPE+ 4% CaCl2 and T_8: LDPE+ 1% $KMnO_4$

Note: Means with same letter in column are not significantly different at p= 0.05 by DMRT. * indicates significant at p<0.05, *** indicates highly significant at p<0.001 and ns: not significantly different at p>0.05, SEm= Standard error of mean, LSD= Least significant difference, CV= Coefficient of Variation, and DAS= Days after storage

Table 5. Effect of plant extracts and chemical treatments under modified atmosphere storage on shelf life and vitamin C content of G-9 banana

Treatment Shelf Life (Days)		Vitamin C (mg/100 g)				
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS
T1	13.67^{g}	13.46	13.09	10.39^{e}	8.50^{e}	-
T2	18.50^{f}	13.46	13.22	11.81^{d}	11.31^{d}	9.63^{e}
T3	22.50^{b}	13.59	13.29	12.41^{c}	11.75^{c}	10.93^{d}
T4	20.17^{e}	13.69	13.21	12.76^{b}	12.23^{b}	11.17^{c}
T5	20.83^{de}	13.63	13.23	12.56^{c}	11.85^{c}	10.88^{d}
T6	21.50^{cd}	13.70	13.30	12.86^{b}	12.16^{b}	11.26^{c}
T7	22.00^{bc}	13.74	13.18	12.86^{b}	12.37^{ab}	11.53^{b}
T8	26.50^{a}	13.52	13.33	13.07^{a}	12.55^{a}	11.83^{a}
SEm (±)	0.30	0.14	0.09	0.05	0.10	0.07
$LSD_{0.05}$	0.91	0.44	0.29	0.16	0.28	0.22
P value	***	ns	Ns	***	***	***
CV, %	2.56	1.89	1.26	0.75	1.45	1.14
Grand mean	20.70	13.62	13.23	12.34	11.59	11.03

T_1: Control, T_2: Low Density Polyethylene bags (LDPE), T_3: LDPE+ 20% garlic extract, T_4: LDPE+ 20% onion extract, T_5: LDPE+ 20% ginger extract, T_6: LDPE+ 20% neem extract, T_7: LDPE+ 4% CaCl2 and T_8: LDPE+ 1% $KMnO_4$

Note: Means with same letter in column are not significantly different at p= 0.05 by DMRT. *** indicates highly significant at p<0.001 and ns: not significantly different at p>0.05, SEm= Standard error of mean, LSD= Least significant difference, CV= Coefficient of Variation, and DAS= Days after storage