EFFECT OF DIFFERENT PLANT EXTRACTS ON POST-HARVEST QUALITY AND SHELF LIFE OF BANANA (*MUSA ACUMINATA* CV. GRAND NAINE)

Nabin Ghimire[1*], Badal Subedi[1] and Ramesh Upreti[2]
[1]School of Agriculture, Far western University, Tikapur, Kailali, Nepal
[2]College of Natural Resource Management CNRM, Tikapur, Kailali, Nepal
[*]Corresponding author email : ghimirenabin813@gmail.com
[*]Nabin Ghimire: https://orcid.org/0009-0007-5161-6875
Badal subedi: https://orcid.org/0009-0003-5592-5406
Ramesh upreti: https://orcid.org/0009-0005-0504-1359

ABSTRACT

Banana is a valuable agricultural product with rising demand over time. However, managing post-harvest losses is a significant challenge due to the highly perishable nature of bananas, which makes them prone to rapid deterioration. An experiment was conducted at the Horticulture Laboratory of the School of Agriculture, Far-Western University during March, 2023 to assess the effect of various plant extracts on quality and shelf life of banana. The experiment used a completely randomized design (CRD) with five treatments: guava leaf (T1), lemon juice (T2), neem leaf (T3), eucalyptus leaf (T4), and a non-treated control (T5), each with four replications. Data were collected from 6 destructive and 6 non-destructive banana samples at 3-day intervals, and analyzed using R studio V 1.1. The study revealed that the plant extracts did not affect banana quality parameters on 3 days but showed significant influence after extended storage. Among the different post-harvest treatments, eucalyptus showed the lowest physiological loss in weight (17.44%), least total soluble solid (16.25),highest tritratable acidity (0.66), highest firmness at (3.02 kg/cm2) until 15 days and declined slightly to (2.75 kg/cm2) at 18 days, highest (24.60) shelf life, long (16.0) days of ripening. While the highest physiological loss in weight (21.14%) and least shelf life (14) was recorded in control. As a result, plants extracts, especially eucalyptus can be utilized to increase the storage life of banana. Hence the study clearly depicted that post-harvest treatments using different plant extracts could be beneficial to prolong the shelf life of banana.

Keywords: *Plant extracts, post-harvest treatments, shelf life, quality, Musa acuminata*

INTRODUCTION

Banana (*Musa Spp*.,) is an oldest and most popular fruit in the world. It is perennial, monocot and monocarpic which is grown in tropical and subtropical parts of the world.

It has a very short storage life and is extremely perishable; making them vulnerable to various diseases that contributes to significant postharvest losses (Shrestha et al., 2018). Banana develops well in temperatures ranging from 15 to 35 °C, coupled with a relative humidity between 75%- 85% Banana, being climacteric fruits, undergoes a speedy ripening process triggered by a self-induced release of the gaseous hormone ethylene. This rapid textural transformation is succeeded by prominent tissue softening, leading to the spoilage of bananas in the later stages of ripening. Apart from the natural aging process, post-harvest losses in fruits are significantly influenced by various infections. Among those, sigatoka, banana streak disease and *Fusarium oxysporium* stand out as the primary diseases affecting banana fruits. These infections lead to speedy deterioration and accelerated decay of the fruits, diminishing their quality and post-harvest lifespan. Preserving the quality of banana fruits while extending their post-harvest duration is a considerable challenge, given their susceptibility to various disease infestations, making them a highly perishable commodity. Consequently, there is a substantial annual crop loss, with post-harvest losses ranging between 25% and 50% (Ghimire et al., 2021).

Numerous techniques and technologies, such as refrigeration, controlled atmosphere (CA) storage, modified atmosphere packaging (MAP), the use of ethylene inhibitors like 1-Methylcyclopropene, plant growth regulator treatment, wax application, and others, have been in application over the years aiming to extend the shelf life and preserve the post-harvest characteristics of fruits (Shrestha et al., 2018). The accessibility and affordability of these advanced technologies for poor farmers in many developing and underdeveloped countries like Nepal pose concerns. In Nepal, a significant number of banana growers face substantial post-harvest losses due to natural deterioration and severe diseases. Quality and quantity of fruits is significantly impacted by the post-harvest diseases. To combat these issues, chemical fungicides are commonly used in banana that include propiconazole, copper hydroxide, pyraclostrobin, and Bordeaux mixture which have become popular for controlling banana post-harvest diseases and extending storage life (George et al., 2019). Nevertheless, utilizing these insecticides increases health and environmental risks, leading to poisoning (Okinbo & Osuinde, 2003). Moreover, frequent application raises the potential for pathogen resistance development in banana (Tripathi et al., 2022). With a growing focus on health and consumer demands for pesticide-free agricultural products, there is an increasing need to explore options that are less expensive, non-toxic, and kind to the environment while having less residual effects. Finding such alternatives is crucial for preventing disease infections and maintaining the post-harvest qualities of banana fruits. Utilizing non-hazardous natural plant extracts from higher plants is a preferable alternative to chemicals for managing post-harvest diseases in banana, ensuring safety for both human health and the environment (Gonçalves et al., 2023). In recent times, extensive research has explored the efficacy of natural plant extracts in the control of post-harvest diseases, revealing numerous instances where botanical extracts demonstrate antifungal properties increasing the shelf life of banana (Israfi et al., 2010). Extensive scientific studies have focused into the antibacterial and antifungal properties of botanical extracts (Bhalodia et al., 2011). These extracts hold potential for substituting or reducing the use of adverse chemicals in post-harvest fruit treatment, effectively managing various diseases due to their proven antimicrobial effects. Given the established antimicrobial qualities of extracts from diverse plant leaves, our study aims to evaluate the practical efficacy of different plant leaf extracts in extending the shelf life and maintaining the quality of harvested bananas in normal storage factors.

MATERIALS AND METHODS

Experimental site

Experiment was carried out in the Horticulture Laboratory of the School of Agriculture at Far Western University Tikapur, Kailali in March, 2023.

Treatment collection

Extracts were acquired from the periphery of the School of Agriculture, Far Western University, consisting of freshly gathered and robust leaves from neem (*Azadirachta indica*), eucylaptus (*Eucalyptus camaldulensis*), guava (*Psidium guajava* L.). Subsequent to the collection, the leaves underwent a cleansing procedure, involving an initial wash with tap water and a final rinse with distilled water. Following that, the leaves were air-dried in the shade at room temperature for a period of 24 hours. Lemon (Citrus lemon) was purchased from a nearby market.

Preparation of plant extract (botanicals)

Fresh guava leaves weighing 500g were gathered from the School of Agriculture, Far Western University and blended with 1000 ml of distilled water. To create 120 ml (12%) of raw guava leaf extract, 180 ml of distilled water was added to the mixture in a 500 ml beaker, resulting in a final volume of 300 ml (Tabassum et al., 2018). Similarly, to produce 60 ml (6%) of raw neem leaf extract, 10 ml of neem leaf juice was extracted from 60 grams of neem leaves and added to 240 ml of distilled water in a 500 ml beaker to achieve a final volume of 300 ml. In the same manner, eucalyptus leaf extract was prepared by combining 90 ml (9%) of raw eucalyptus leaf extract obtained from 90 grams of leaves, with 250 ml of distilled water in a 500 ml beaker to attain a final volume of 300 ml (Tabassum et al., 2018). In contrast, for the preparation of Lemon Extract (LE), 45 ml (4.5%) of lemon juice extract was combined with 285 ml of distilled water and blended (Mia, 2003). The melded samples underwent filtration using filter paper, and the filtrate was stored in aluminum foil-sealed beakers in the refrigerator at 5°C for 24 hours until usage. Following that, the fruit samples were dipped in the prepared extracts for 5 minutes and placed on sterilized surfaces in five groups, with three replications of every treatment.

Collection and preparation of fruit samples

Mature green stage bananas of the 'Grand Naine' variety, harvested freshly, were obtained from the University's banana orchard. The selected bananas were of uniform size, maturity, and high quality, with no signs of injury or disease. To ensure cleanliness, the fruits underwent thorough cleaning with distilled water, eliminating foreign particles such as dust, dirt, and mud. Following the cleaning process, the bananas were categorized based on similar sizes after another round of washing with distilled water, and these grouped fruits were utilized for the experiment. The cleansed bananas were immersed in the prepared leaf extracts for duration of 10-15 minutes and then stored under ambient room conditions at between 32±2ºC and 65±5% RH.

Experimental design and treatments preparation

The experiment was conducted in Completely Randomized Design (CRD) with five treatments and four replications. Six destructive samples were kept for each replication for carrying out chemical analysis. The five treatments were as: T1: Guava leaf extract, T2: Lemon juice extract, T3: Neem leaf extract, T4: eucalyptus leaf extract, T5: Control. Each treatment was composed of 12 bananas.

Observations

Observations were made on the following parameters:

Physiological weight loss (%)

It was determined with the help of electronic digital balance.

$$\text{W}ight\ loss\ \% = \frac{Initial\ Weight - Final\ weight}{Initial\ Weight} \times 100$$

Total soluble solids (°Brix)

The total soluble solids (°Brix) was recorded every alternate day by using hand held Abbe’s refractometer. A drop of banana juice was placed on the refractometer's prism, and the percentage TSS was read off on the scale of refractometer immediately.

Firmness (kg/cm²)

Firmness of fruits was measured using LUTRON Fruit Hardness Tester EQL-FR-5120 after peeling thin layer of skin holding banana on table.

Titratable acidity

By titrating diluted fruit juice with a few (2–3) drops of phenolphthalein against a base solution (0.1N NaOH), tratable acidity was measured. Titratable acidity was determined every alternate day by using the formula described by (Tabassum et al., 2018; Khan and Singh 2008) as follows-

$$Titratable\ Acidity = \frac{0.0067 \times Vol.of\ NAOH \times 30 \times 100}{5 \times 10}$$

Where, 0.0067 = Milli-equivalent weight of malic acid; 30 = Total volume (ml); 5 = Extracted juice sample (ml); 10 = Volume of aliquot (ml).

Ripening days

Based on visual observations and the perception of softness, we were able to observe changes in sample. Furthermore, noted the number of days it took for the ripening process to begin (Ankit et al., 2018).

Shelf life

The point at which over 50% of the stored fruits became unsuitable for consumption was regarded as the end of the shelf life in that specific treatment (Padmalatha, 1995).

Statistical analysis

Using R studio V 1.1 statistical package, the gathered data on various parameters were methodically organized and statistically analyzed to determine the variation arising from experimental treatments. The F-test was used to perform analyses of variances (ANOVA) for all the parameters after the means for each treatment were determined. The LSD (least significance difference) test was used to examine the significance of the difference between the two means at the 5% probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Physiological loss in weight (%)

It was evident from Table 1, that there was significant difference in PLW due to different treatments during the experimental period expect in 3 days. The differences in PLW% between treatments were statistically significant from 6 days onwards. At 6 days and onwards, eucalyptus leaf extract showed the lowest PLW% indicating it was most effective at slowing down deterioration. On the 6th day, highest PLW% was recorded in control (11.43%) whereas lowest percentage of PLW was recorded in eucalyptus leaf extract treated banana (8.90%) which was statistically par with neem extract treated banana. On 9th and 12th days, the highest percentage of PWL was found in control (14.2%) and (17.90%) whereas, eucalyptus treated banana experienced lowest percentage of PWL (9.81%) and (14.68%) which was followed by neem extract treated banana. During 15th days, the control (21.14%) maximum PWL and eucalyptus treated banana fruits (17.44%) minimum physiological weight loss was observed followed by neem extract treated banana. Higher PLW% indicates greater moisture loss and deterioration. The control bananas had the highest PLW% at each storage duration, indicating they deteriorated faster without any botanical treatment. All the botanical treatments helped reduce PLW% compared to control, showing they have protective effects against moisture loss and can extend banana shelf life. Guava leaf extract and lemon juice extracts showed lower efficacy than eucalyptus, but were still better than control. Eucalyptus leaf extract was the most effective botanical treatment tested for extending shelf life of bananas by preventing moisture loss (lowest PLW%).

This finding is in line with the reports of (Duree et al. 2023) who reported that the use of eucalyptus leaf extract can help reduce the physiological weight loss of bananas and increase their shelf life. The superior performance of eucalyptus leaf extract in minimizing PLW% can be attributed to its ability to retard ripening and senescence processes, enabling the treated bananas to maintain intact peels for longer durations. This offers better surface barrier protection against transpirational water loss, as suggested by Islam et al. (2014). Additionally, eucalyptus and other botanical extracts are thought to induce biochemical changes that restrict metabolic activities, suppress respiration rates, and reduce fruit porosity (Brinston et al. 1988), thereby slowing moisture loss.

Table 1. Effect of different plant extracts in physiological loss in weight of banana (*Musa acuminata* cv. Grand Naine)

Treatments	3 Days	6 Days	9 Days	12 Days	15 Days
T1:Guava leaf extract	5.01[a]	10.06[c]	13.09[ab]	15.49[bc]	18.20[bc]
T2:Lemon Juice extract	4.86[a]	10.74[b]	12.37[b]	16.35[b]	19.48[b]
T3:Neem leaf extract	4.94[a]	9.34[d]	11.79[b]	15.56[bc]	18.45[bc]
T4: Eucalyptus leaf extract	5.17[a]	8.90[d]	9.81[c]	14.68[c]	17.44[c]
T5: Control (not treated)	5.58[a]	11.43[a]	14.26[a]	17.90[a]	21.14[a]
LSD (0.05)	0.92	0.67	1.75	1.42	1.62

F-test	NS	***	**	**	**
SEM (±)	0.31	0.22	0.58	0.47	0.54
Grand Mean	5.11	10.09	12.26	15.99	18.94

Note: DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, NS: Non-Significant, SEM: Standard Error of the Mean, LSD: Least Significant Difference

Total Soluble Solid (TSS)

It is evident from Table 2 that there were no significant differences in TSS between the treatments until 3 days of storage. However, from 12 days onwards, statistically significant differences were observed between the treatments in their effects at retarding ripening as measured by lower TSS levels. The control bananas showed the fastest increase in TSS ^{0}brix over storage period, registering the highest levels of TSS at 12 days (16^0 brix), 15 days (18^0 brix) and 18 days (20.5^0 brix) storage durations. This indicates the control fruits ripened the fastest in absence of any botanical treatment. Among the botanical extracts, eucalyptus leaf extract was the most effective at slowing down ripening and had lower TSS levels from 12 days until 18 days storage compared to other treatments. At 18 days, it registered a TSS of 16.25^0 brix compared to 20.5^0 brix in control. Guava leaf extract was the next best treatment in retarding ripening after eucalyptus leaf extract. Neem leaf extract treated fruits showed statistically similar TSS as lemon juice extract during most storage durations and showed poor efficacy in retarding ripening among the botanicals tested, with the TSS being closer to control fruits and significantly higher than other botanical treatments at 15 days (15.25^0 brix and 15.75^0 brix) and 18 days (18.25^0 brix and 18.75^0 brix) respectively.

The initial rise in TSS levels across all treatments is likely attributed to the natural ripening-related breakdown of starch and other complex carbohydrates into simple soluble sugars in the bananas during post-harvest storage. Previous research by Kumar et al., (2007) has proposed that enzymes hydrolyze insoluble starch into more soluble sugar moieties as fruits ripen, elevating TSS. However, the slower increase in TSS in eucalyptus-treated bananas is likely due to a thin oil coat formed after dipping, which acts as a physical barrier. This film restricts gaseous exchange, limiting CO2 diffusion and oxygen uptake, and reduces moisture loss. These effects slow down metabolism and ripening processes, leading to a more gradual rise in soluble sugars compared to other treatments, as also suggested by Maryem (2000).

Table 2. Effect of different plant extracts in total soluble solids of banana (^{0} brix) (*Musa acuminata* L. cv. Grand Naine)

Treatments	3 Days	6 Days	9 Days	12 Days	15 Days	18 Days
T1:Guava leaf extract	4.5^{a}	6.75^{b}	10.25^{b}	13.25^{ab}	15^{b}	17.75^{bc}
T2:Lemon Juice extract	5.75^{a}	8.75^{a}	10.5^{ab}	13^{b}	15.25^{b}	18.25^{b}
T3:Neem leaf extract	5.75^{a}	7^{ab}	10.5^{ab}	13^{b}	15.75^{ab}	18.75^{b}
T4: Eucalyptus leaf extract	4.75^{a}	7.25^{ab}	9.5^{b}	11^{b}	14.5^{c}	16.25^{c}
T5: Control (not treated)	4.25^{a}	8^{ab}	12^{a}	16^{a}	18^{a}	20.5^{a}
LSD (0.05)	3.16	1.84	1.71	2.77	2.29	1.74
F-test	NS	NS	NS	*	**	**
SEM (±)	1.0488	0.609	0.5664	0.92	0.76	0.58
Grand Mean	5	7.55	10.55	13.25	15.30	18.30

Note: DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, NS: Non-Significant, SEM: Standard Error of the Mean, LSD: Least Significant Difference

Titratable acidity

Titratable acidity indicates the organic acid level and is an index of ripening. TA% decreases with ripening as acids get utilized. Higher TA% means slower ripening. It is evident from Table 3 that significant differences in TA% existed between the treatments at each measurement day, indicating varyingly efficacy in delaying ripening process. Control bananas showed fastest drop in TA% during storage, registering 0.39% at 3 days to 0.44% at 18 days. This rapid reduction indicates faster ripening of control fruits. Among the botanical extracts, eucalyptus leaf extract showed best efficacy in retarding ripening as it displayed highest TA retention throughout storage duration from 0.49% at 3 days to 0.66% at 18 days.Neem leaf extract also showed good efficacy with TA% higher than control and on par with eucalyptus extract at some durations. Lemon juice and guava leaf extracts were moderately effective with slight TA% increments over control. The results showing eucalyptus leaf extract as superior for retaining fruit acidity concur with Muhammad et al. (2022). In their independent study on botanical extracts for shelf-life extension of sapota fruit, they found 1.5% eucalyptus extract retained the highest titratable acidity (0.63%) after 2 weeks storage.

Table 3. Effect of different plant extracts in titratable acidity of banana (*Musa acuminata* L. cv. Grand Naine)

Treatments	3 Days	6 Days	9 Days	12 Days	15 Days	18 Days
T1:Guava leaf extract	0.37[b]	0.41[b]	0.46[c]	0.47[b]	0.54[c]	0.51[c]
T2:Lemon Juice extract	0.4[b]	0.445[b]	0.44[c]	0.50[c]	0.50[d]	0.49[c]
T3:Neem leaf extract	0.45[a]	0.54[a]	0.56[b]	0.58[d]	0.60[b]	0.59[b]
T4: Eucalyptus leaf extract	0.49[a]	0.56[a]	0.62[a]	0.66[a]	0.67[a]	0.66[a]
T5: Control (not treated)	0.39[b]	0.41[b]	0.42[c]	0.49[cd]	0.48[d]	0.44[d]
LSD (0.05)	0.04	0.05	0.06	0.03	0.04	0.04
F-test	**	**	**	**	**	**
SEM (±)	0.01	0.01	0.02	0.01	0.01	0.04
Grand Mean	0.42	0.472	0.50	0.54	0.56	0.54

Note: DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, SEM: Standard Error of the Mean, LSD: Least Significant Difference

Firmness

Fruit firmness indicates ripening stage, with lower values denoting loss of firmness and ripening. It is evident from Table 4 that significant differences existed in firmness between the treatments at each measured day, indicating varyingly efficacy in maintaining firmness and delaying ripening. Control bananas showed fastest and greatest loss in firmness over storage period, dropping severely from 3.45 kg/cm^2 at 3 days to 0.83 kg/cm^2 by 15 days and staying lowest till 18 days. This large firmness decline indicates rapid ripening of control fruits. Among botanical extracts, eucalyptus leaf extract showed maximum efficacy in retaining fruit firmness for longest duration. The firmness of eucalyptus treated fruits remained highest at 3.02 kg/cm^2 until 15 days and declined slightly to 2.75 kg/cm^2 at 18 days. Neem leaf extract also showed good efficacy, while lemon juice and guava leaf extracts displayed moderate effectiveness compared to control. Eucalyptus leaf extract demonstrated highest efficacy in delaying ripening process of bananas by retaining fruit firmness for prolonged storage duration.

The superior performance of eucalyptus leaf extract can be attributed to its bioactive compounds, which might possess antimicrobial and antioxidant properties that slow down the enzymatic activities responsible for ripening. This is consistent with the observations of Brinston et al. (1988), who noted that retaining firmness during ripening is associated with preventing the breakdown of insoluble pectin into soluble pectin and avoiding cellular disintegration, thereby maintaining membrane integrity. Eucalyptus extract may help in maintaining firmness by slowing the processes that lead to pectin breakdown and cellular disintegration. Similarly, control bananas ripened fastest as observed from drastic firmness losses over time. Islam et al. (2014) also noted that all other botanical treatments led to the decrease in firmness, with the control bananas showing the fastest rate of changes in firmness.

Table 4. Effect of different plant extracts in firmness of banana (*Musa acuminata* L. cv. Grand Naine)

Treatments	3 Days	6 Days	9 Days	12 Days	15 Days	18 Days
T1:Guava leaf extract	3.40^{a}	3.17^{bc}	3.11^{ab}	2.91^{a}	1.56^{cd}	1.38c
T2:Lemon Juice extract	3.40^{a}	3.26^{a}	3.06^{b}	2.91^{a}	2.02^{bc}	1.60^{c}
T3:Neem leaf extract	3.17^{b}	3.12^{c}	3.19^{a}	3.02^{a}	2.72^{ab}	2.20^{b}
T4: Eucalyptus leaf extract	3.35^{a}	3.21^{ab}	3.12^{ab}	3.06^{a}	3.02^{a}	2.75^{a}
T5: Control (not treated)	3.45^{a}	2.34^{d}	1.38^{c}	0.83^{b}	0.83^{d}	0.83^{d}
LSD (0.05)	0.12	0.08	0.12	0.17	0.76	0.53
F-test	**	**	**	**	**	**
SEM (±)	0.04	0.03	0.04	0.06	0.25	0.18
Grand Mean	3.35	3.02	2.77	2.54	2.03	1.75

Note: DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, SEM: Standard Error of the Mean, LSD: Least Significant Difference

Ripening days

The Table 5 depicts data from an experiment that evaluated the efficacy of various botanical extracts - guava leaf, lemon juice, neem leaf, eucalyptus leaf, compared with untreated control bananas, in influencing the ripening period (in days) of bananas stored under ambient conditions. It is evident that significant differences existed between extracts in extending the ripening period of bananas during storage. Control untreated fruits displayed fastest ripening, taking only 8.25 days to attain full ripeness from harvesting. This offers a comparative benchmark for assessing efficacy of the botanical extracts in delaying ripening process. Among the botanical extracts tested, eucalyptus leaf extract showed maximum efficacy and extended ripening duration up to 16 days, resulting in ~2X longer shelf life than control bananas. Neem leaf extract also showed reasonably good effectiveness, prolonging ripening to 14.75 days over control. Lemon juice and guava leaf extracts demonstrated moderately beneficial impacts in retarding ripening and achieving ripening periods of 13.5 and 13.75 days respectively. Eucalyptus leaf extract was found to be the most potent botanical treatment for delaying ripening process thereby enhancing post-harvest life of banana fruits under ambient storage. The control bananas ripened fastest taking only 8.25 days to attain full ripening. Eucalyptus leaf extract, as supported by Muhammad et al. (2022), effectively extends banana shelf life, surpassing other botanical extracts like neem, lemon, and guava, without synthetic chemicals.

Table 5. Effect of different plant extracts in ripening days of banana (*Musa acuminata* L. cv. Grand Naine)

Treatments	Ripening Days
T1:Guava leaf extract	13.75[ab]
T2:Lemon Juice extract	13.5[ab]
T3:Neem leaf extract	14.75[b]
T4: Eucalyptus leaf extract	16[a]
T5: Control (not treated)	8.25[c]
LSD (0.05)	1.62
F-test	**
SEM (±)	0.54
Grand Mean	13.25

Note: CV: Coefficient of Variance, DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, SEM: Standard Error of the Mean, LSD: Least Significant Difference

Shelf life

The Table 6 shows efficacy of various botanical treatments – guava leaf, lemon juice, neem leaf, eucalyptus leaf extracts and untreated control in extending postharvest shelf life of bananas measured in days, as evident from the significant variation between treatments. It is clear that control untreated bananas had shortest shelf life of 14.01 days before becoming unsaleable, offering a baseline for comparison. Among the botanical extracts, eucalyptus leaf extract showed maximum potency and prolonged shelf life period to the highest extent adding ~10 extra usable days with 24.26 days total shelf life compared to control. Neem leaf extract also conferred reasonably good increment in extending shelf life by ~7 additional days to 21.11 days versus control. Lemon juice and guava leaf extracts showed moderately beneficial impacts providing only marginal increments of 1 to 2 days extra over that of control bananas. The research findings, consistent with Reddy & Rao (2021) in Sapota, show that eucalyptus extract outperforms other botanicals in extending postharvest longevity. The superior efficacy of eucalyptus extract in extending postharvest longevity compared to other botanicals could be attributed to its unique biochemical composition, which may include specific compounds with potent anti-ripening properties (Brinston et al. 1988). Additionally, eucalyptus extract may interact more effectively with the physiological processes involved in fruit ripening, leading to prolonged shelf life.

Table 6. Effect of different plant extracts in shelf life of banana (*Musa acuminata* L. cv. Grand Naine)

Treatments	Shelf life (days)
T1:Guava leaf extract	14.88[cd]
T2:Lemon Juice extract	15.27[c]
T3:Neem leaf extract	21.11[b]
T4: Eucalyptus leaf extract	24.26[a]
T5: Control (not treated)	14.01[d]
LSD (0.05)	1.17
F-test	**
SEM (±)	0.39
Grand Mean	17.90

Note: CV: Coefficient of Variance, DMRT (Duncan's Multiple Range Test) at 5%, values in a column containing the same letters do not differ significantly, SEM: Standard Error of the Mean, LSD: Least Significant Difference

CONCLUSION

The research paper concludes on the superior performance of eucalyptus extract in preserving post-harvest banana quality and prolonging the shelf life by retarding physiological weight loss, reducing ripening rate, and enabling extended retention of firmness compared to untreated fruits. After eucalyptus, neem leaf extract also conferred reasonably good post-harvest life extension of bananas, while lemon juice and guava leaf extracts showed moderate efficacy. All the botanicals outperformed the controls across measured indices. Therefore, the application of eucalyptus and neem botanical extracts offers an effective, non-hazardous and practical approach for small-scale banana farmers to minimize postharvest losses due to accelerated ripening and decay, thereby facilitating enhanced incomes. Also the botanical extracts provide a cost-effective and eco-friendly alternative to synthetic chemicals for postharvest treatment of bananas.

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