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Effect of Different Plant Extracts and $KMnO_4$ in the Shelf Life and Quality of Banana cv. Malbhog

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Abstract

Poor storage, microbial decay, uneven ripening and the presence of chemical residue are the major postharvest problems of banana. This experiment was conducted to analyze the performance of various plant extracts and $KMnO_4$ on the shelf and the quality of bananas at the Horticultural Laboratory of Gauradaha Agriculture Campus, Gauradaha, Jhapa. The experiment was carried out in a Completely Randomized Design (CRD) with seven treatments and three replications. Each treatment consists of 12 banana fingers. Banana fruits were treated with neem extract (1:1), aloe vera gel (100%), onion extract (1:1), ginger extract (1:1), sweet flag extract (1:1) and $KMnO_4$ (5gm) which were compared with non-treated fruits (control). 900 ml of each plant's extracts were used for the experiment. The data on different post-harvest parameters were recorded at 3 days intervals for 12 days at ordinary laboratory conditions. The result showed that the lowest weight loss (8.82%), pulp to peel ratio (4.71), color (5.66 score) and highest firmness (4 score) was reported on aloe vera gel. The neem leaf showed minimum moisture content (62.13%) and the highest TSS (25.41^0 Brix) was observed in control at 6 days after treatment. The minimum TA (0.17%), DI (29.62 %) and disease severity (3 score) were reported on sweet flag extract. The longest shelf life (12 days) was observed in banana fruits treated with sweet flag extract and aloe vera gel. In conclusion, sweet flag extract and aloe vera gel could be suggested for better shelf life and quality of banana.

Keywords: Aloe vera, chemical, disease, post-harvest, sweet flag

Introduction

Banana is an economically important fruit crop of Nepal with an average area, production and productivity of 21633 ha., 308388 Mt. and 15.97 Mt/ha. respectively (MoALD, 2022). Banana is highly perishable fruit owing to rapid physiochemical changes such as an increase in respiration, transpiration and ethylene production, change in peel color and pulp texture, change in aroma and flavor and increase in weight loss and total soluble solid (TSS) which ultimately led to senescence, spoilage and sever postharvest loss (Basal et al., 2002; Decosta and Erabadupitiya, 2005; Misir et al., 2012). These changes start immediately after harvesting and reduced the quality and shelf life of the banana. A study carried out by Deshmukh et al. (2018), reported that net post-harvest losses in banana constitute 5.36 % loss at field level, 4.88 % loss during the transit 5.90 % loss at wholesaler's level, 7.68 % loss at ripening storage level and 14.82 % loss at retailers' level. Poor storage, microbial decay, uneven ripening and the presence of chemical residue are the major postharvest problems of banana. Depending on genotype, maturity stage at harvest and storage and handling conditions, bananas have an average market life of 1 to 10 days at ambient tropical temperatures. Preventing microbial spoilage and reducing ethylene buildup around produce are the key strategies to improve the shelf life of bananas. For this, post-harvest treatment of fruits with chemicals have been practiced commercially (Mari et al., 2003). But these chemicals are harmful to human health, the environment and other living organisms (Sharma, 2015; Shahbaz et al., 2022). With the intensive use of such chemicals, the pathogens have also developed resistance against those fungicides (Murmu and Mishra, 2018). In this context, safer alternative strategies have been developed by the banana industries globally to prolong the shelf life. Among different alternatives, the treatment of bananas with different plant extracts (neem, onion, aloe vera gel, garlic, ginger) have shown antimicrobial properties with variable degrees of controlling postharvest diseases (B.A. et al.,

2019; Das et al., 2021; Chandra Mandal, 2016; Timilsina & Shrestha, 2022). Thus, this experiment was undertaken to investigate the efficacy of some locally available plant extracts (sweet flag, aloe vera, neem, onion and ginger) on the shelf life and quality of banana.

Materials and methods

Experimental location

This research was carried out in the Horticultural Laboratory of Gauradaha Agriculture Campus, Gauradaha, Jhapa from 15th August to 27th August 2022. This place has a humid tropical climate. The average annual temperature and relative humidity of the location are 26.5^{0}C and 61% respectively (DHM, 2020).

Selection of Cultivar

Freshly harvested banana fruits of the variety Malbhog from the 4-year-old banana orchard of Pathivara Krishi Farm, Gauradaha-1 were taken for the experiment. 252 fingers of fully mature bananas free from diseases with approximately uniform shape, size and color were selected for the experiment.

Design of experiment

The experiment was conducted in a completely randomized design (CRD) with seven treatments and three replications. There are twelve banana fingers per replicate.

Treatment details

Banana fruits were treated with neem extract (1:1), aloe vera gel (100%), onion extract (1:1), ginger extract (1:1), sweet flag extract (1:1) and $KMnO_4$ (5gm) which were compared with non-treated fruits (control).

Table 1. Details of treatments

Treatment number	Treatments name
T_1	Control
T_2	Neem extract
T_3	Aloe vera gel
T_4	Onion extract
T_5	Ginger extract
T_6	Sweet flag extract
T_7	$KMnO_4$

Preparation of plant extract

Initially, a stock of plant extract was prepared by blending fresh neem leaves, onion bulb, ginger rhizome and fresh sweet flag rhizome with distilled water using a blender for the respective plant extracts. The blended content was then filtered through clean muslin clothes. The plant extract was prepared by using the stock solution and distilled water in a ratio of 1:1. The aloe vera pulp was blended with a blender machine to obtain the aloe vera gel (100%). 900 ml of each plant's extracts were prepared for the experiment.

Treatment of fruits with plant extracts

The fruits were then dipped into the plant extract solutions for 5 minutes and the treated fruits were allowed to air dry for a period of 10 minutes and then kept for observation. 5 gm $KMnO_4$ powder was kept in tissue paper and placed in a perforated bag. Eight perforations of 4 mm diameter were made in each plastic bag. The treated bananas were kept in ambient room conditions with a mean temperature of 31.42±1.05^{0}C and relative humidity of 73.75±2.41% from 15th August to 27th August.

Observation taken

Various physical parameters, such as weight, color and firmness, were recorded every three days from the day of the experiment. Additionally, parameters such as TSS (Total Soluble Solids), TA (Titratable Acidity), moisture content and peel to pulp ratio were also recorded every three days. Furthermore, disease incidence and severity were recorded on subsequent data collection days following their appearance.

Physiological Weight loss (PLW)

The banana fingers used in this study were weighed using an electronic weighing machine and kept for storage. Percent total weight loss was calculated by using the formula suggested by Kaur (2016) as follows:

$$\text{PLW (\%)} = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100\%$$

Color change

Changes in skin color were recorded based on eye estimation by using a numerical scale of 1-7 (Dadzie & Orchard, 1997).

Where, 1= 100% green, 2= 1-25% yellow, 3= 26-50 %, 4= 51-75% yellow, 5= 76-100% yellow, 6= fully yellow and 7= rotten.

Firmness

Change in firmness was recorded based on the feel method by using a numerical scale of 1-5 (Dang et al., 2008) where 1= hard, 2= sprung, 3= slightly soft, 4= eating soft and 5= over soft.

Pulp to peel ratio (PPR)

The fruits were peeled from each replication. After separating the peel from the pulp, the peel and pulp were weighed separately using an electric balance and then the PPR was calculated.

$$\text{PPR} = \frac{Weight\ of\ fruit\ pulp}{Weight\ of\ peel}$$

Moisture content (MC)

Five grams of banana pulp were weighed in a Petri dish from each treatment out of each replication. The Petri dish was placed in an electric oven at 80°C for 72 hours until the weight became constant. It was then cooled and weighed again. Finally, the percent moisture content of banana pulp was calculated using the following formula:

$$\text{MC (\%)} = \frac{Initial\ fresh\ weight\ of\ pulp - Final\ weight\ of\ oven\ dried\ pulp}{Initial\ fresh\ weight\ of\ pulp} \times 100\%$$

Total soluble solids (TSS)

The TSS content of banana fruit pulp was estimated by using a Hand refractometer. Banana pulp was blended in the blender to get juice and the drop of juice was placed on the prism of the refractometer. Percent TSS was obtained from a direct reading of the instrument.

Titratable acidity (TA)

The TA was recorded from the 6th day. The acidity was estimated as per the standard procedures of Horwitz & Latimer (2005). A total of 10 ml of the clear juice of fruit from each treatment was taken and titrated against standard 0.1 N of sodium hydroxide (NaOH) solution using phenolphthalein as an indicator. Then the titratable acidity of the fruit was expressed in percentage using the following formula:

$$\text{TA (\%)} = \frac{NB \times VB \times MEFA}{Vs} \times 100\%$$

where TA = titratable acidity (%), NB = normality of the base (NaOH), VB = volume of the base (ml), MEFA = milliequivalent factor of the predominant acid, i.e., malic acid (0.0067) and V_S = volume of sample.

Disease incidence (DI)

The fruit rot of the banana under observation was identified by the visual comparison with those of the symptoms already published. The incidence of fruit rot was calculated by the given equation, suggested by Ullah (2007) as follows:

$$\text{DI (\%)} = \frac{Number\ of\ infected\ fruits}{The\ total\ number\ of\ fruits\ under\ the\ study} \times 100\%$$

Disease severity (DS)

All the infected fruits were selected to determine the percent fruit area infected. The percentage of fruit area diseased was measured based on eye estimation. The mean values regarding the infected fruit area were calculated. The assessment of this selection ends up completed subjectively via ratings related to the following scale tailor-made by Azevedo (1998):

1. Very bad – more than 50% of fruit with lesions, impossible to be made good use of; 2. Bad – lesions between 25 and 50% of fruit, not much exploitable; 3. Tolerable – lesions between 5 and 25% of fruit, not acceptable for trading, can be used as home consumption; 4. Good – lesions up to 5% of fruit, conditions acceptable for trading; 5. Excellent – without lesions.

Shelf life

The shelf life of a banana treated with different treatments was calculated by counting the number of days until the score for firmness retains less than or equal to 4, disease severity retains more than or equal to 3 and the color score attains less than or equal to 6. The number of days for attaining a loss of 25% weight was also considered to calculate shelf life. The average of the days required to reach the mentioned level of the considered parameters was recorded as the shelf life of fruits.

Statistical Analysis

The data were entered into Microsoft Excel (2019) and analysis was carried out by using the software R-Studio (4.2.1). The data were analyzed using a two-way ANOVA (Analysis of Variance) table and the mean separation was done by DMRT (Duncan's Multiple Range Test) at a 5% level.

Results

Color change

Analysis of variance shows that the effect of plant extracts and $KMnO_4$ was significant for color change of banana. On 9 days after treatment (DAT), control, onion extract and $KMnO_4$ treated fruits crossed the acceptable color limit, however, aloe vera gel (5.66 score), neem leaf extract (6 score), sweet flag extract (6 score) treated fruits maintained the acceptable color limit for 3 more days.

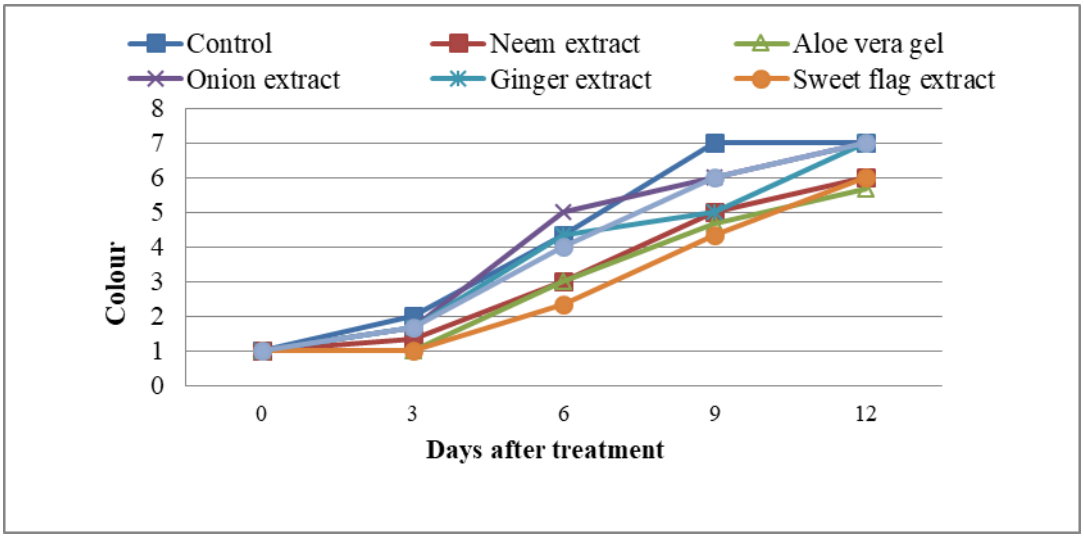

Figure 1. *Effect of plant extracts and $KMnO_4$ on color change*

Physiological Weight Loss (PLW%) and Pulp to Peel Ratio (PPR)

Despite the coatings, fruits in all treatments showed significant variation in weight loss over the course of storage. Maximum PLW was seen in control (8.54%, 8.2%) while the minimum PLW was recorded in sweet flag extract (4.84% and 3.75%) at 3 and 6 DAT respectively. At day 9 and 12 DAT, aloe vera gel (6.17% and 8.82%) followed by sweet flag (6.5% and 9.8%) extract had the greatest impact on lowering PLW, whereas $KMnO_4$ (14.7%) at 9 DAT and Neem extract (10.1%) at 12 DAT had the highest PLW. However, it was statistically similar to sweet flag and aloe vera gel at day 12 DAT.

The PPR obtained had statistically significant variation between the treatments at various storage days. Untreated fruit showed the highest PPR (3.16 and 4.18) at 3 and 6 DAT respectively. On day 12, the highest PPR (4.87) was noticed in neem extract-treated banana, whereas, the lowest PPR (1.5, 2.35, 3, 4.71) was found on aloe vera gel treated banana at 3,6,9 and 12 DAT, which was statistically similar with neem leaf extract and sweet flag.

Table 2. Effect of different plant extracts and KMnO4 on PLW% and PPR of banana

Treatments	PWL (%)				PPR			
	3 DAT	6 DAT	9 DAT	12 DAT	3 DAT	6 DAT	9 DAT	12 DAT
Control	8.54^{a}	8.64^{a}	100^{a}	100.00^{a}	3.16^{a}	4.18^{a}	0.00^{d}	0.00^{b}
Neem extract	5.56^{ab}	4.64^{bc}	6.91^{d}	10.10^{b}	2.10^{bc}	2.76^{b}	4.07^{ab}	5.04^{a}
Aloe Vera gel	5.14^{b}	3.76^{c}	6.17^{d}	8.82^{b}	1.50^{c}	2.35^{b}	3.00^{c}	4.71^{a}
Onion extract	6.18^{ab}	6.27^{abc}	11.95^{bc}	100.00^{a}	3.013^{ab}	4.10^{a}	4.24^{ab}	0.00^{b}
Ginger extract	7.59^{ab}	5.44^{bc}	9.00^{cd}	100.00^{a}	$2.36a^{bc}$	2.64^{b}	3.53^{bc}	0.00^{b}
Sweet flag extract	4.84^{b}	3.75^{c}	6.50^{d}	9.80^{b}	1.92^{c}	2.50^{b}	3.33^{bc}	4.87^{a}
$KMnO_4$	5.65^{ab}	6.81^{ab}	14.70^{b}	100.00^{a}	2.02^{bc}	2.93^{b}	4.62^{a}	0.00^{b}
Grand mean	6.21	5.61	22.17	61.24	2.29	3.07	3.25	2.08
F value	2	4.55	718.6	1650	3.83	6.53	24.68	18.74
MS error	2.77	2.07	5	4	0.28	0.26	0.28	0.10
LSD	2.91^{NS}	2.52**	3.91**	3.50**	0.92*	0.89**	0.94**	0.57**
CV (%)	26.80	25.64	10.08	3.26	23.06	16.71	16.49	15.7

*means “significant at 0.05” and **means “significant at 0.01”, ^{NS}=non-significant CV (%) =coefficient of variance, LSD= least significant difference.

TSS and TA

The plant extracts significantly affected TSS during storage. The maximum TSS was recorded in the control (13.02^{0} Brix,25.41^{0} Brix) at 3 and 6 DAT respectively. At 9 DAT highest TSS (24.50^{0} Brix) and lowest TSS (22.44^{0} Brix) were seen in onion extract and aloe vera gel respectively. Minimum TSS was found in the sweet flag extract (23.11^{0} Brix) at 12 DAT which was statistically at par with aloe vera gel and neem leaf extract.

A significant variation was found in the TA of the current study. The minimum TA was found in sweet flag extract (0.27 %, 0.17%) at 3 DAT and 12 DAT while the maximum was recorded in aloe vera gel (0.31%, 0.28% and 0.20%) at 6, 9 and 12 DAT. Table 2. Effect of different plant extracts and $KMnO_4$ on TSS and TA of banana

Table 3. Effect of different plant extracts and KMnO4 on TSS and TA of banana

Treatments	TSS (^{0}Brix)				TA (%)		
	3 DAT	6 DAT	9 DAT	12 DAT	6 DAT	9 DAT	12 DAT
Control	13.02^{a}	25.41^{a}	0.00^{c}	0.00^{b}	0.30^{b}	0.00^{c}	0.00^{c}
Neem extract	8.52^{b}	22.26^{b}	23.37^{ab}	23.51^{a}	0.30^{ab}	0.25^{ab}	0.18^{ab}
Aloe Vera gel	7.04^{bc}	18.52^{d}	22.44^{b}	23.37^{a}	0.3^{a}	0.28^{a}	0.20^{a}
Onion extract	11.57^{a}	21.37^{bc}	24.50^{a}	0.00^{b}	0.29^{bc}	0.23^{b}	0.00^{c}
Ginger extract	8.33^{bc}	22.39^{b}	24.24^{a}	0.00^{b}	0.28^{c}	0.23^{ab}	0.00^{c}
Sweet flag extract	6.84^{c}	19.72^{cd}	22.46^{b}	23.11^{a}	0.27	0.25^{ab}	0.17^{b}
$KMnO_4$	11.93^{a}	21.19^{bc}	23.4^{ab}	0.00^{b}	0.29^{bc}	0.22^{b}	0.00^{c}
Grand mean	9.60	21.55	20.06	9.99	0.29	0.21	0.07
F value	26.84	9.33	352.7	4.51	0.57	36.84	280.5
MS error	0.70	1.54	0.67	0.3	4.29e-05	0.00	0.00
LSD	1.47**	2.17**	1.43**	0.95**	0.11^{NS}	0.04**	0.017**
CV (%)	8.75	4.07	4.07	5.47	21.30	12.90	12.96

*means “significant at 0.05” and **means “significant at 0.01”, ^{NS}=non-significant
CV (%) =coefficient of variance, LSD= least significant difference.

Firmness and moisture content (%)

Despite the coatings, fruits in all treatments showed significant variation in firmness over the course of storage. Before 6 DAT, there was no difference in the firmness of bananas. The highest reduction in firmness was observed in control (3.66 score and 4.33 score) at 6 and 9 DAT respectively. The lowest reduction in firmness was seen in sweet flag extract (1.33 and 3 score) treated fruits at 6 and 9 DAT. At 12 DAT minimum firmness reduction was observed in aloe vera gel (4.00 score) which was statistically at par with sweet flag extract and neem extract treated fruits.

The result showed that moisture content gradually decreased with postharvest treatment during storage. The moisture content was highest (72.8%) in control and lower (67.96%) in the sweet flag at 3 days of storage. Untreated bananas had higher (74.8%) moisture content at 6 DAT. The lowest (66.73%, 63.06% and 62.13%) moisture content was noticed in neem leaf extract-treated banana which was at par with sweet flag and aloe vera at 6, 9 and 12 DAT respectively.

Table 4. Effect of different plant extracts and KMnO4 on firmness and moisture content of banana

Treatments	Firmness (score)					MC (%)			
	0 DAT	3 DAT	6 DAT	9 DAT	12 DAT	3 DAT	6 DAT	9 DAT	12 DAT
Control	1^{a}	1^{a}	3.66^{a}	5.00^{a}	5.00^{a}	72.80^{a}	74.8^{a}	0.00^{c}	0.00^{b}
Neem extract	1^{a}	1^{a}	1.33^{b}	3.00^{d}	4.33^{b}	68.6^{bc}	66.73^{c}	63.06^{b}	62.13^{a}
Aloe Vera gel	1^{a}	1^{a}	1.66^{b}	3.00^{d}	4.00^{b}	68.83^{bc}	67.06^{c}	66.44^{ab}	66.00^{a}
Onion extract	1^{a}	1^{a}	2.66^{ab}	4.00^{bc}	5.00^{a}	70.66^{abc}	69.13^{bc}	68.08^{ab}	0.00^{b}
Ginger extract	1^{a}	1^{a}	1.66^{b}	3.66^{c}	5.00^{a}	70.66^{abc}	69.87^{bc}	68.66^{ab}	0.00^{b}
Sweet flag extract	1^{a}	1^{a}	1.33^{b}	3.00^{d}	4.33^{b}	67.96^{c}	68.00^{bc}	63.13^{b}	65.74^{a}
$KMnO_4$	1^{a}	1^{a}	3.33^{a}	4.33^{b}	5.00^{a}	71.7^{ab}	72.19^{ab}	71.42^{a}	0.00^{b}
Grand mean	1	1	2.23	3.71	4.66	70.13	69.68	57.34	27.69
F value	1	1	3.75	19.17	5.83	3.09	5.06	204.8	698
MS error	4.43e-31	4.43e-31	0.76	0.09	0.09	9.21	5.05	9.5	5
LSD	1.16e-15NS	1.16e-15NS	1.527*	0.54**	0.54**	2.98*	3.93**	5.39**	3.91**
CV (%)	6.66e-14	6.66e-14	39.00	8.30	6.61	2.43	3.22	5.37	8.07

*means "significant at 0.05" and **means "significant at 0.01", ^{NS}=non-significant
CV (%) =coefficient of variance, LSD= least significant difference.

Disease incidence (DI) and disease severity (DS)

The DI obtained had statistically significant variation between the treatments at various storage days. No DI was recorded before 6 DAT. No DI was found in the sweet flag extract and aloe vera gel till 6 DAT with minimum DI (6.06%) recorded in both neem extract and ginger extract and the highest in control (37.36%). The highest DI was recorded in $KMnO_4$ (60%) and neem (37.03%) at 9 DAT and 12 DAT respectively. The minimum DI (13.33%, 29.62%) was recorded in sweet flag extract at 9 and 12 DAT.

There was a significant effect of plant extract on the DS of bananas. No DS was observed before 6 DAT. At 6 DAT the maximum DS was observed in control (2.33 score) and no DS was seen in aloe vera gel and sweet flag extract having a 5 score. On day 9 control, onion extract, ginger extract and $KMnO_4$ treated fruits exceeded the acceptable DS limit. Aloe vera gel (3 score), sweet flag extract (3 score) and neem extract (2.66 score) treated fruits maintained the acceptable DS limit up to 12 DAT.

Table 5. Effect of different plant extracts and KMnO4 in the DI and DS

Treatments	DI (%)			DS (score)		
	6 DAT	9 DAT	12 DAT	6 DAT	9 DAT	12 DAT
Control	37.36^{a}	100^{a}	100.00^{a}	2.33^{c}	1.00^{d}	1.00^{b}
Neem extract	6.06^{b}	23.33^{cd}	45.83^{b}	4.33^{ab}	3.00^{b}	2.66^{a}
Aloe Vera gel	0.00^{b}	13.33^{d}	37.03^{bc}	5.0^{a}	4.00^{a}	3.00^{a}

Treatments	DI (%)			DS (score)		
	6 DAT	9 DAT	12 DAT	6 DAT	9 DAT	12 DAT
Onion extract	24.24^{ab}	40.00^{bc}	100.00^{a}	3.33^{bc}	2.00^{c}	1.00^{b}
Ginger extract	6.06^{b}	36.66^{bcd}	100.00^{a}	4.00^{ab}	2.33^{bc}	1.00^{b}
Sweet flag extract	0.00^{b}	13.33^{d}	29.62^{c}	5.00^{a}	4.00^{a}	3.00^{a}
$KMnO_4$	36.52^{a}	60.00^{b}	100.00^{a}	2.66^{c}	1.66^{cd}	1.00^{b}
Grand mean	15.74952	40.95	73.21	3.80	2.57	1.80
F value	4.38	17.62	44.63	10.29	16.67	65
MS error	188.5	161.9	76	0.33	0.23	0.04
LSD	24.04*	22.28**	15.26**	1.01**	0.85*	0.38**
CV (%)	87.17	31.07	11.90	15.14	18.97	12.05

*means "significant at 0.05" and **means "significant at 0.01", ^{NS}=non-significant
CV (%) =coefficient of variance, LSD= least significant difference.

Shelf life

The result showed that there was a significant difference among the different treatments. A longer shelf life (12 days) was observed in sweet flag extract and aloe vera gel coated fruits as compared to non-coated fruits. A statistically similar result (11.66 days) was noticed in fruits coated with neem leaf extract. The shelf life of ginger extract, onion extract coated fruits and $KMnO_4$ were (10.66 days), (10 days) and (9.66 days) respectively whereas, the lowest shelf life (8 days) was observed in non-coated fruits.

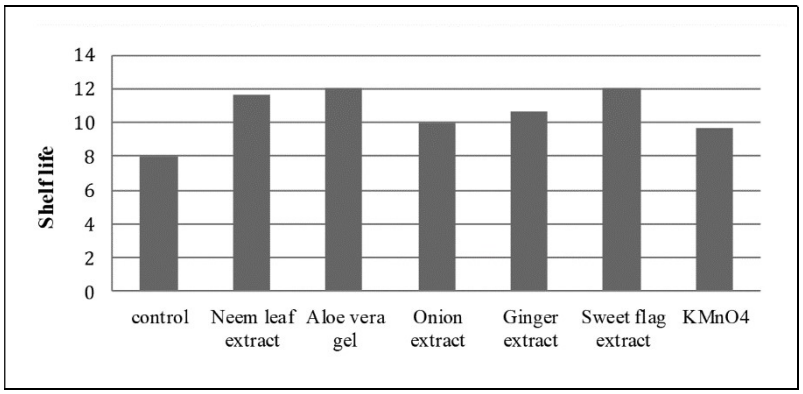

Figure 2. *Effect of plant extracts and KMnO4 on shelf life of banana*

Discussion

Ripening of fruit is associated with a series of physical, physiological and perceptible changes. Fruits' peel colors changed as they ripened and matured and these changes might be due to chlorophyll degradation or the qualitative and quantitative conversion of green pigment into other pigments. Aloe vera gel coating changed the environment, slowing ethylene production, which subsequently slowed fruit ripening, chlorophyll degradation, anthocyanin accumulation and carotenoid synthesis (Carrillo-Lopez et al., 2000). Cantos et al. (2002) and Ergun & Satici (2012) also reported the degradation of green pigment was less in the fruits coated with aloe vera gel.

The loss of water from the peel, microbial deterioration and storage room environments such as temperature and humidity, all contributed to the weight loss of bananas (Hossain & Iqbal, 2016). Aloe vera gel is hygroscopic in nature which enable the development of a barrier to water diffusion between the fruit and the environment, which reduced weight loss in coated fruit (Martínez-Romero et al., 2006). Ozturk et al. (2019) and Valverde et al. (2005), also reported fruits coated with aloe vera gel minimized weight loss and extended the shelf life of fruits.

According to Pathak & Sanwal (1999), the PPR of banana fruits increased during ripening. The difference in sugar concentration between the pulp and peel during storage might be the cause of the increased ratio, which would then lead to significant osmotic pressure variations. Both transpiration and osmosis cause water to be lost from banana peels. As a consequence of this, the peel weight decreases and the PPR rises (Timilsina & Shrestha, 2022). Because

of osmotic differences, the pulp's rapid increase in sugar concentration causes water to flow from the pulp to the peel (Dadzie & Orchard, 1997). The delayed ripening of aloe vera gel coated bananas might be due to a slower change in the PPR.

The increase in TSS content during storage might be attributed to moisture loss, polysaccharide hydrolysis and juice concentration due to degradation (Acharya et al., 2020). The rise in TSS was due to the breakdown of complex sugars into simple sugars (Kittur et al., 2001). The rise in TSS is consistent with the fact that starch hydrolysis and conversion to sugar are key indicators of fruit ripening in climacteric fruits like bananas (Das et al., 2021). According to Chauhan & Joshi (1990), botanical extracts had a better record of maintaining the TSS in the mango of Ratna cv. Aloe-pectin edible coating could help limit this rise of TSS to some extent (Valverde et al., 2005). Neem oil applied to fruit surfaces lowered evapotranspiration and respiration rates and showed minimal degradation, preventing a sharp increase in TSS (Singh et al., 2000).

The various treatments using plant extracts significantly slowed down the maturing processes. The drop in TA in banana fruit after storing is linked to the fall in organic acid concentration (Thakur et al., 2019). According to Muangdech, (2016) Coating maintains an adaption state, increasing CO_2, which inhibits ethylene activity, delaying ripening and slowing changes in the quantity of TA inside the vacuole. Aloe vera and chitosan-coated mango showed a lower reduction in TA (Ochiki et al., 2015). Aloe vera gel and chitosan coating helped in TA maintenance (Nabigol & Asghari, 2013). According to Doreyappa Gowda & Huddar (2001), the drop in TA for uncoated fruits is caused by the transformation of acids into sugars and their subsequent utilization in the fruit's metabolic processes.

Firmness is a crucial quality that customers look for and is often responsible for fruit acceptability. Martínez-Romero et al. (2006), found aloe vera treated sweet cherries were effective in maintaining firmness since there were no significant changes in treated sweet cherries during cold storage and further shelf life while there was accelerated softening in non-treated fruits. According to Ullah et al. (2006), the reduced firmness of control samples was linked to increased water loss and softening of tissues of banana skin. Furthermore, the firmness of the banana is directly affected by the degradation of the cell wall and the transformation of starch (Hou et al., 2015). The aloe treatment substantially reduced firmness losses throughout cold storage in jujube fruits (Padmaja et al., 2014). These findings support our study.

The moisture content of the fruit was moderately reduced throughout the storage period. This might be due to the fact that when a higher relative humidity is maintained in the storage room, pre-cooled products lose moisture more slowly. Neem leaf extract is an effective postharvest treatment for preserving most of the postharvest attributes and prolonging banana shelf life when kept in ambient storage conditions (Siddiqua et al., 2018). This is also supported by the experiment conducted by Wijewardane & Guleria (2010).

Asha & Ganjewala (2009), assessed the antimicrobial activity of *A. calamus* rhizomes and leaves extracted using several solvents, including petroleum ether, chloroform, hexane and ethyl acetate, against fungal infections and found that these extracts showed substantial antifungal activity. Sweet flag has secondary metabolites with insecticidal, antibacterial and antifungal characteristics, which are crucial for food preservation (Miao et al., 2015). *Acorus calamus* oil extracted with supercritical fluid revealed antifungal effectiveness against various fungus species with various activities (Singh et al., 2010). Our study also showed less DI and DS which is supported by the above studies.

Conclusion

Plant extracts showed a significant effect on the shelf life and quality of bananas. The lowest PLW%, PPR, color change and highest firmness were observed in aloe vera gel. Minimum moisture content was observed in the neem extract. The highest TSS was noted in control and sweet flag extract was found to be best in reducing disease incidence, disease severity and TA. Among different plant extracts, sweet flag extract and aloe vera gel showed the longest shelf life followed by neem extract. Considering the overall quality attributes and shelf life, aloe vera gel and sweet flag extract can be alternatives to chemicals as an economically viable and environmentally friendly approach.

Declaration of conflict of interest and ethical approval:

There is no potential conflict of interest between authors.

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