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Effect of $KMnO_4$ on shelf life and quality of banana (*Musa paradisiaca* L.)

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ABSTRACT

Banana being a climacteric fruit shows an increase in ethylene production during the ripening which reduces the shelf life. Potassium permanganate ($KMnO_4$) as an ethylene absorber extends the shelf life and maintains postharvest quality. The experiment was conducted at the laboratory of Nepal Polytechnic Institute, Bharatpur-11, Chitwan, Nepal from 2nd August to 13th August 2018 to investigate the effect of different concentrations of $KMnO_4$ on post-harvest qualities of banana at ambient conditions (30.35 ± 2.15 °C and 82 ± 5.5% RH). The experiment consisted of five different concentrations of $KMnO_4$ *viz.* 0, 2, 4, 6 and 8 grams (g) per seven fingers of banana. The research was laid out in a Complete Randomized Design (CRD) with four replications. Among different concentrations of $KMnO_4$, 4 g $KMnO_4$ showed the minimum weight loss on 4, 8 and 12 days which was 0.66%, 2.55% and 5.93% respectively. The maximum shelf life (13.50 days), titratable acidity (1.89%) and firmness (4.47 lb) was recorded in 6 g $KMnO_4$. The highest total soluble solids (18.30%) was obtained in 0 g $KMnO_4$. Thus at ambient room conditions (30.35 ± 2.15 °C and 82 ± 5.5% RH), it is suggested to use 6 g $KMnO_4$ per seven fingers of banana fruits to reduce post-harvest loss.

Keywords: Banana, post-harvest, potassium permanganate, shelf life

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1 Introduction

Banana (*Musa paradisiaca* L.) belonging to the family of Musaceae, is a large herb with pseudostem built up from leaf sheaths. It is one of the most important and commonly grown fruits of the tropical regions of the world as it is available throughout the year and is relatively inexpensive. In Nepal, banana is widely cultivated both in tropical and sub-tropical regions. In Nepal, during the period of 2018/19, the productive area of bananas was 16,615 hectares with a production of 278,890 metric tonnes (MoALD, 2020). In the Chitwan district, during the period of 2018/19, the productive area of bananas was 1,412 hectares with a production of 26,432 metric tonnes (MoALD, 2020).

Banana is a climacteric fruit and increases its respiration rate and ethylene production during the ripening process (Calberto et al., 2012). Because of the climacteric nature of bananas, they can't be stored for a long time under normal conditions. The short post-harvest life limits the local and international trade which is a major problem in banana cultivation, especially in developing countries. Thus, improvement of shelf life and quality of bananas with the application of post-harvest treatment is necessary. The use of ethylene absorber minimizes the effect of ethylene on

fruit which helps to extend shelf life and ensure post-harvest quality to some extent. Potassium permanganate ($KMnO_4$) is a strong oxidizing stable purple solid that readily oxidizes ethylene (Wills and Warton, 2004). $KMnO_4$ is quite effective in reducing ethylene levels as it oxidizes ethylene into carbon dioxide (CO_2) and water (Elzubeir et al., 2017). $KMnO_4$ is well known as an effective postharvest anti-ethylene component to extend the longevity of perishable fruits (Sujayasree and Fasludeen, 2017). Ketsa et al. (2000) and El-Naby (2010) reported delays in ripening and improvement of post-harvest quality of banana with the application of $KMnO_4$. The use of potassium permanganate for ethylene removal retards the ripening of bananas (de Souza Prill et al., 2012). In the presence of $KMnO_4$, bananas can also be transported at higher ambient temperatures by packing in polyethylene-lined boxes (Kader, 2002). The Chitwan district of Nepal is one of the most potential district for banana farming (Shrestha et al., 2018). The post-harvest loss of bananas is about 10-15% in Chitwan, which is more than mango, citrus, and apple (Joshi et al., 2020). The use of potassium permanganate can play an important role to minimize post-harvest loss of bananas. Considering these facts, the experiment has been conducted in Chitwan to evaluate the effect of different concentrations of $KMnO_4$ on the post-harvest life and quality of banana at ambient conditions (30.35 $\pm$ 2.15 °C and 82 $\pm$ 5.5% RH).

2 Materials and Methods

2.1 Experimental site

The experiment was conducted in the laboratory of Nepal Polytechnic Institute, Bharatpur-11, Chitwan, Nepal during 2nd August to 13th August, 2018. Geographically, it is located at 27.69 °N latitude, 84.44 °E longitude and an elevation about 256 meters above sea level. The temperatures and relative humidity of the storage rooms were recorded by a thermo hygrometer (HTC brand, model IT-202) (Fig. 1).

2.2 Experimental details

The experiment was laid out in Complete Randomized Design (CRD) with four replications, having five treatments in each replication. Freshly harvested bunches of green but mature unripe bananas were brought from the commercial banana farm at Padampur, Chitwan. The variety of banana used in the study was Malbhog. The bunches were dehanded and divided into fingers. The fruits of uniform shape, size, color and free from blemishes were selected and washed with tap water to remove latex, latex stains, soil and other dust particles and then air-dried. Low-density polythene bags of 25 micron thickness were used for the packing of bananas. Each polythene bag with four perforations was used. Perforations on the bags were made using an ordinary punching machine of a diameter 6 mm. Seven fingers of banana were packed in each low-density perforated polythene bag and kept at room temperature for their quality assessment. Five concentrations of potassium permanganate ($KMnO_4$) *viz*. 0, 2, 4, 6 and 8 grams (g) were kept in the tissue paper and placed in their respective perforated polythene bags. Then polythene bags packed with fruits were kept at ambient room condition (30.35 $\pm$ 2.15 °C and 82 $\pm$ 5.5% RH).

2.3 Observations

2.3.1 Weight loss

The fruit samples were weighed on a digital weighing balance on the first day and continued at 4, 8 and 12 days. The loss in weight during the storage was expressed in percent and calculated using the following formula:

$$WL\ (\%) = \frac{W_I - W_F}{W_I} \tag{1}$$

where WL = weight loss(%), W_I = initial weight (g), and W_F = final weight (g) of fruit sample.

2.3.2 Shelf life

The shelf-life of fruit was based on the development of discoloration i.e. blackened skin, off-flavor, fungal attack and skin shriveling. The stage at which more than 50% of the stored fruits became unsuitable for consumption was considered as the end of shelf-life.

2.3.3 Total soluble solids (TSS)

TSS (%) was determined by using a refractometer (Erma brand, ERB-32 model having a reading range from 0-32%) on the first and the last day of storage.

2.3.4 Titratable acidity (TA)

TA was determined on the first and last day of the research. The acidity was estimated as per standard procedures of (AOAC, 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:

$$TA\ (\%) = \frac{N_B \times V_B \times MEF_A}{V_s} \times \tag{2}$$

where TA = titratable acidity (%), N_B = normality of the base (NAOH), V_B = volume of the base (mL), MEF_A = milliequivalent factor of the predominant acid, i.e. citric acid (0.0064).

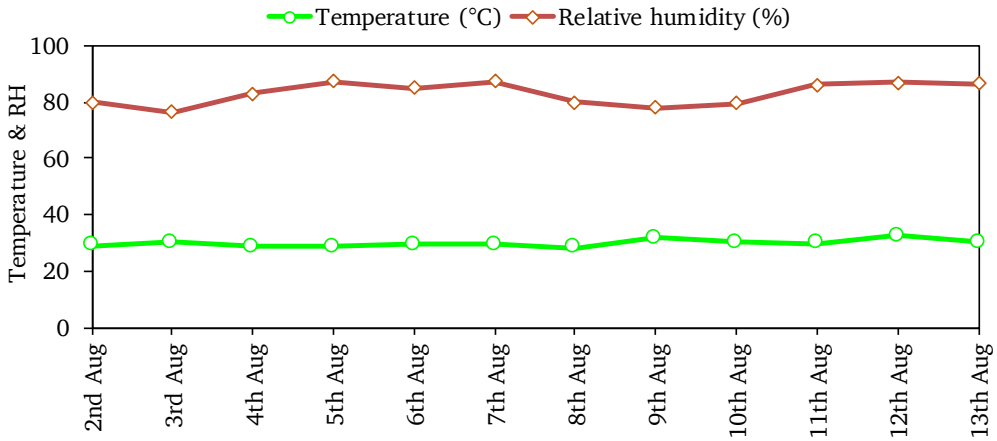

Figure 1. Temperature and relative humidity of the laboratory during the experiment

2.3.5 Flesh firmness

Fruit firmness was measured on the first and last dates of the research. Fruit firmness was recorded by a fruit pressure tester (TR Turoni brand, model FT 327) and expressed in pounds (lb).

2.4 Statistical analysis

The recorded data were analyzed by Genstat software. Data was subjected to Analysis of Variance (ANOVA) to evaluate the significant treatment effects. The treatment means were compared by the Least Significant Difference (LSD) test at 5% (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Weight loss

Different concentrations of $KMnO_4$ showed a significant effect on weight loss at 4, 8 and12 days after storage (Table 1). The maximum weight loss was recorded at 0 g concentration of $KMnO_4$ which was 4.30% (4 days), 10.56% (8 days) and 16.53% (12 days) while the lowest weight loss was recorded at 4 g concentration of $KMnO_4$ which was 0.66% (4 days), 2.55% (8 days) and 5.93% (12 days), it is because $KMnO_4$ delays in the fruit ripening which decreases tissue permeability and a decrease in tissue permeability reduce the weight loss (Elzubeir et al., 2017). Elamin and Abu-Goukh (2009) in banana, Islam (2012) in papaya, Elzubeir et al. (2017) in banana and Shalini et al. (2018) in kiwifruits, Tasmim et al. (2020) in mango also recorded a low weight loss due to the application of $KMnO_4$ compared to control. As expected, the weight loss increased upon daily storage in all treatments (Table 1) due to the continuous loss of moisture caused by the transpiration and respiration process (Nath et al., 2011).

3.2 Shelf life of banana

Different concentrations of $KMnO_4$ showed a significant effect on the shelf life of bananas (Table 2). The maximum shelf life (13.50 days) was obtained in 6 g $KMnO_4$ followed by 12.50 days on 4 g $KMnO_4$ while the 0 g $KMnO_4$ showed the minimum shelf life (9.31 days). The respiration and the rate of deterioration of horticultural commodities are directly proportional (Sujayasree and Fasludeen, 2017). The use of $KMnO_4$ decreases respiration rate and delays the onset of the climacteric peak in bananas (Elamin and Abu-Goukh, 2009). Further, $KMnO_4$ absorbs ethylene and degrades it to CO_2 and water which increases CO_2 content in the storage atmosphere (Lopez et al., 1995; Elzubeir et al., 2018). An increase in the concentration of CO_2 blocks the synthesis of endogenous ethylene (Miyazaki and Yang, 1987; Frígola, 2016). $KMnO_4$ absorbs ethylene due to which the activity of chlorophyllase and change in color of banana peel is reduced which increases the green life (Bhattacharjee and Dhua, 2017) and increasing green life increases shelf life. In this way, $KMnO_4$ increases green life, delays the senescence process and increases the shelf life. Elamin and Abu-Goukh (2009) reported that potassium permanganate delays fruit ripening and extension of shelf life of banana fruits. de Souza Prill et al. (2012) obtained delay ripening and senescence with the use of $KMnO_4$ in bananas. Azad et al. (2010) in mango and Ahmed et al. (2021) in banana have also found more shelf life with the application of $KMnO_4$.

3.3 Total soluble solids (TSS)

Different concentrations of $KMnO_4$ showed a significant effect in the TSS (%) (Table 2). The result showed that the TSS increased during storage (Table 2). The water loss leads to a higher concentration of sugar in fruits during storage (Bhattarai and Gautam, 2006). Further, moisture loss, hydrolysis of polysaccharides

Table 1. Effect of different concentrations of $KMnO_4$ on physiological loss in weight of banana

Treatments	Weight loss (%)		
	4 days	8 days	12 days
0 g $KMnO_4$	4.30a	10.56a	16.53a
2 g $KMnO_4$	2.73b	4.79b	8.52c
4 g $KMnO_4$	0.66c	2.55d	5.93d
6 g $KMnO_4$	0.70c	2.87c	6.01d
8 g $KMnO_4$	2.73b	4.71b	9.02b
Mean	2.22	5.09	9.20
LSD (0.05)	0.44***	0.40***	0.52***
CV (%)	6.30	2.50	1.80

Treatments means followed by the common letter or letters within the column are not significantly different among each other at a 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, and *** = Significant at P≤0.001

Table 2. Effect of different concentrations of $KMnO_4$ on shelf life and TSS of banana

Treatments	Shelf life	TSS (%)	
		Initial value	Final value
0 g $KMnO_4$	9.31d	6.00	18.30a
2 g $KMnO_4$	11.25c	6.00	16.30b
4 g $KMnO_4$	12.50b	6.00	14.70d
6 g $KMnO_4$	13.50a	6.00	14.97c
8 g $KMnO_4$	11.25c	6.00	16.72b
Mean	11.56	6.00	16.19
LSD (0.05)	0.66***		0.37***
CV (%)	1.80		0.70

Treatments means followed by the common letter or letters within the column are not significantly different among each other at a 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, and *** = Significant at P≤0.001

and conversion of juice as a result of degradation contribute towards the increase in TSS during storage (Mir et al., 2018; Tasmim et al., 2020). The highest TSS (18.30%) was found in 0 g $KMnO_4$ and the lowest TSS (14.70%) was obtained in 4 g $KMnO_4$. Other treatments also recorded low TSS as compared to 0 g $KMnO_4$ (Table 2). The high TSS in 0 g $KMnO_4$ indicates accelerated ripening. The low TSS in $KMnO_4$ treated fruit might be due to the ethylene absorbing capacity of $KMnO_4$ which delayed the ripening of fruits (Zewter, 2012). Azad et al. (2010) in mango, Elamin and Abu-Goukh (2009) in banana, Silva et al. (2009) in papaya, (Elzubeir et al., 2018) in mango also obtained less TSS with the application of $KMnO_4$ as compared to without $KMnO_4$ during storage.

3.4 Titratable acidity (TA)

Different concentrations of $KMnO_4$ showed a significant effect in TA (Table 3). TA was decreased in all the treatments during storage (Table 3), this is because TA is a quantitative measure of organic acids which decreases with the senescence process (Latifah et al., 2013). Further, the utilization of acid for the production of flavoring compounds during ripening also decreases the TA during storage (Bhattarai and Gautam, 2006). Although there was a decrease in TA during storage, the highest TA (1.89%) was obtained at 6 g $KMnO_4$ followed by 1.87% at 4 g $KMnO_4$ while the lowest TA (0.55%) was obtained at 0 g $KMnO_4$. It might be because the use of $KMnO_4$ increases the CO_2 concentration as CO_2 is a byproduct of ethylene degradation (Sammi and Masud, 2007) and an increase in CO_2 concentration forms carbonic acid in the fruit that causes acidosis (Lopez et al., 1995; Sammi and Masud, 2007). Rouf (2012) in banana, Mujtaba et al. (2014) in tomato and Kaur and Kaur (2018) in banana recorded the highest TA with the application of $KMnO_4$.

Table 3. Effect of different concentrations of $KMnO_4$ on titratable acidity and firmness of banana

Treatments	TA (%)		Firmness (lb)	
	Initial value	Final value	Initial value	Final value
0 g $KMnO_4$	2.48	0.55d	11.50	0.20c
2 g $KMnO_4$	2.48	1.76b	11.50	3.70b
4 g $KMnO_4$	2.48	1.87a	11.50	3.85b
6 g $KMnO_4$	2.48	1.89a	11.50	4.47a
8 g $KMnO_4$	2.48	1.36c	11.50	3.80b
Mean	2.48	1.48	11.50	3.20
LSD (0.05)		0.06***		1.06***
CV (%)		1.40		10.60

Treatments means followed by the common letter or letters within the column are not significantly different among each other at a 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, and *** = Significant at $P \leq 0.001$

3.5 Firmness

A significant effect of different concentrations of $KMnO_4$ was observed for firmness (Table 3). The firmness was decreased in all the treatments during storage (Table 3) which might be due to the disturbance in cell integration due to ripening changes initiated by pectin enzymes, pectin methylesterase (PME) and polygalacturonase (PG) (Sharma et al., 2010). It might be also due to the breakdown of the cell walls, decrease in the bond of middle lamella caused by the dilution of the pectic substances and movement of water from the skin to the flesh as a result of osmosis during ripening (Zewter, 2012). The highest firmness (4.47 lb) was obtained in 6 g $KMnO_4$ and the lowest firmness (0.20 lb) was recorded in 0 g $KMnO_4$. Other treatments also recorded high firmness than 0 g $KMnO_4$. It might be due to the absorption of ethylene by $KMnO_4$ from the package and the prohibition of the activity of the enzyme system triggered by ethylene (Lidster et al., 1985; Shalini et al., 2018). Further $KMnO_4$ inhibits the growth of *Botrytis cinerea* that causes losses of firmness of fruit (Bombelli et al., 2006). Kaur and Kaur (2018) obtained the improvement in firmness and the highest firmness in bananas with the application of $KMnO_4$. Elamin and Abu-Goukh (2009) in banana, Rahemi and Saiary (2002) in Golden Delicious variety of apple, Bal and Celik (2010) in kiwifruits and Shalini et al. (2018) in kiwifruits also observed similar result.

Although the highest concentration of $KMnO_4$ was 8 g, it was unable to perform well. It might be because $KMnO_4$ oxidizes ethylene into CO_2 and water but a high dose of $KMnO_4$ might have increased the concentration of CO_2 more than the amount required to block the endogenous synthesis of ethylene. Then the high concentration of CO_2 might have created stress in fruits and ethylene production might have increased due to stress instead of decreasing. Ahmed et al. (2021) reported a decreasing trend in ethylene emission up to a certain concentration of $KMnO_4$ while an increase in ethylene emission and a decrease in post-harvest quality after a certain concentration of $KMnO_4$ in banana i.e. at high concentrations of $KMnO_4$.

4 Conclusion

Based on the above results it can be concluded that 6 g $KMnO_4$ showed the maximum shelf life, TA and firmness. Thus at ambient room conditions (30.35 $\pm$ 2.15 °C and 82 $\pm$ 5.5% RH), it is suggested to use 6 g $KMnO_4$ per seven fingers of banana fruits to reduce post-harvest loss and increase shelf life.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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