**Effect of KMnO₄ on shelf life and quality of banana (Musa paradisiaca L.)**

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**Article Information**

**ABSTRACT**

Banana being a climacteric fruit shows an increase in ethylene production during the ripening which reduces the shelf life. Potassium permanganate (KMnO₄) as an ethylene absorber extends the shelf life and maintains post-harvest 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 KMnO₄ 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 KMnO₄ 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 KMnO₄, 4 g KMnO₄ 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 KMnO₄. The highest total soluble solids (18.30%) was obtained in 0 g KMnO₄. Thus at ambient room conditions (30.35 ± 2.15 °C and 82 ± 5.5% RH), it is suggested to use 6 g KMnO₄ per seven fingers of banana fruits to reduce post-harvest loss.

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

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 (Sujaysree 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 ± 2.15 °C and 82 ± 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 ± 2.15 °C and 82 ± 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:

\[ WL(\%) = \frac{W_I - W_F}{W_I} \]  

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:

\[ TA(\%) = \frac{N_B \times V_B \times MEF_A \times 100}{V_s} \]  

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).
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 and 12 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 (Sujayasee 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; Frigola, 2016). KMnO$_4$ absorbs ethylene due to which the activity of chlorophyllase and change in color of banana peel is reduced which increases 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 KMnO₄ on physiological loss in weight of banana

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 days</td>
</tr>
<tr>
<td>0 g KMnO₄</td>
<td>4.30a</td>
</tr>
<tr>
<td>2 g KMnO₄</td>
<td>2.73b</td>
</tr>
<tr>
<td>4 g KMnO₄</td>
<td>0.66c</td>
</tr>
<tr>
<td>6 g KMnO₄</td>
<td>0.70c</td>
</tr>
<tr>
<td>8 g KMnO₄</td>
<td>2.73b</td>
</tr>
<tr>
<td>Mean</td>
<td>2.22</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.44***</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.30</td>
</tr>
</tbody>
</table>

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 KMnO₄ on shelf life and TSS of banana

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shelf life</th>
<th>TSS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial value</td>
<td>Final value</td>
</tr>
<tr>
<td>0 g KMnO₄</td>
<td>9.31d</td>
<td>6.00</td>
</tr>
<tr>
<td>2 g KMnO₄</td>
<td>11.25c</td>
<td>6.00</td>
</tr>
<tr>
<td>4 g KMnO₄</td>
<td>12.50b</td>
<td>6.00</td>
</tr>
<tr>
<td>6 g KMnO₄</td>
<td>13.50a</td>
<td>6.00</td>
</tr>
<tr>
<td>8 g KMnO₄</td>
<td>11.25c</td>
<td>6.00</td>
</tr>
<tr>
<td>Mean</td>
<td>11.56</td>
<td>6.00</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.66***</td>
<td>0.37***</td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.80</td>
<td>0.70</td>
</tr>
</tbody>
</table>

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 KMnO₄ and the lowest TSS (14.70%) was obtained in 4 g KMnO₄. Other treatments also recorded low TSS as compared to 0 g KMnO₄ (Table 2). The high TSS in 0 g KMnO₄ indicates accelerated ripening. The low TSS in KMnO₄ treated fruit might be due to the ethylene absorbing capacity of KMnO₄ 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 KMnO₄ as compared to without KMnO₄ during storage.

3.4 Titratable acidity (TA)

Different concentrations of KMnO₄ 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 KMnO₄ followed by 1.87% at 4 g KMnO₄ while the lowest TA (0.55%) was obtained at 0 g KMnO₄. It might be because the use of KMnO₄ increases the CO₂ concentration as CO₂ is a byproduct of ethylene degradation (Sammi and Masud, 2007) and an increase in CO₂ 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 KMnO₄.
Table 3. Effect of different concentrations of KMnO₄ on titratable acidity and firmness of banana

<table>
<thead>
<tr>
<th>Treatments</th>
<th>TA (%)</th>
<th>Firmness (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial value</td>
<td>Final value</td>
</tr>
<tr>
<td>0 g KMnO₄</td>
<td>2.48</td>
<td>0.55d</td>
</tr>
<tr>
<td>2 g KMnO₄</td>
<td>2.48</td>
<td>1.76b</td>
</tr>
<tr>
<td>4 g KMnO₄</td>
<td>2.48</td>
<td>1.87a</td>
</tr>
<tr>
<td>6 g KMnO₄</td>
<td>2.48</td>
<td>1.89a</td>
</tr>
<tr>
<td>8 g KMnO₄</td>
<td>2.48</td>
<td>1.36c</td>
</tr>
<tr>
<td>Mean</td>
<td>2.48</td>
<td>1.48</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>0.06***</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>1.40</td>
</tr>
</tbody>
</table>

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 KMnO₄ 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 KMnO₄ and the lowest firmness (0.20 lb) was recorded in 0 g KMnO₄. Other treatments also recorded high firmness than 0 g KMnO₄. It might be due to the absorption of ethylene by KMnO₄ 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 KMnO₄ 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 KMnO₄. Elamin and Abu-Goukh (2009) in banana, Rahemi and Saiary (2002) in Golden Delicious variety of apple, Bai and Celik (2010) in kiwifruits and Shalini et al. (2018) in kiwifruits also observed similar result.

Although the highest concentration of KMnO₄ was 8 g, it was unable to perform well. It might be because KMnO₄ oxidizes ethylene into CO₂ and water but a high dose of KMnO₄ might have increased the concentration of CO₂ more than the amount required to block the endogenous synthesis of ethylene. Then the high concentration of CO₂ 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 KMnO₄ while an increase in ethylene emission and a decrease in post-harvest quality after a certain concentration of KMnO₄ in banana i.e. at high concentrations of KMnO₄.

4 Conclusion

Based on the above results it can be concluded that 6 g KMnO₄ showed the maximum shelf life, TA and firmness. Thus at ambient room conditions (30.35 ± 2.15 °C and 82 ± 5.5% RH), it is suggested to use 6 g KMnO₄ 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.

References


Frigola A. 2016. Role of potassium permanganate ethylene on physicochemical properties, during storage of five different tomato cultivars. MOJ Food Processing & Technology 3:281–289. doi: 10.15406/mofpt.2016.03.00069.


Rahemi M, Saiary M. 2002. Effect of warming, CaCl₂ and potassium permanganate on storability of Golden delicious variety of apple. MS Thesis, Agriculture Faculty, Shiraz University, Shiraz, Iran.

Rouf MA. 2012. Effects of different postharvest treatments on shelf life and quality of banana. MS Thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh.


