International Journal of Food Science and Agriculture, 2021, 5(1), 41-51
http://www.hillpublisher.com/journals/jsfa/
ISSN Online: 2578-3475
ISSN Print: 2578-3467

Potassium Permanganate ($KMnO_4$) in Relation to Temperatures Alters Shelf Life and Quality of Banana (*Musa paradisiaca* L.)

Zaheer Ahmed[1], Tanveer Fatima Miano[1,*], Tahseen Fatima Miano[2]

[1]Department of Horticulture, Sindh Agriculture University Tandojam, Pakistan.
[2]Institute of Food Sciences and Technology Sindh Agriculture University Tandojam, Pakistan.

How to cite this paper: Zaheer Ahmed, Tanveer Fatima Miano, Tahseen Fatima Miano. (2021) Potassium Permanganate (KMnO4) in Relation to Temperatures Alters Shelf Life and Quality of Banana (*Musa paradisiaca* L.). *International Journal of the Science of Food and Agriculture*, 5(1), 41-51.
DOI: 10.26855/ijfsa.2021.03.007

Received: December 15, 2020
Accepted: January 10, 2021
Published: January 25, 2021

***Corresponding author:** Tanveer Fatima Miano, Department of Horticulture, Sindh Agriculture University Tandojam, Pakistan.
Email: drtanveerfmiano@yahoo.in

Abstract

Respiration rate and ethylene production during ripening process causes the banana fruit to deteriorate rapidly and shorten its shelf life. Keeping in view the significance of this issue a laboratory study was carried out during 2019 at the Department of Horticulture SAU Tandojam to determine the effect of potassium permanganate at different concentrations (0, 1%, 2% and 3%) on quality and shelf life of banana under low ($7^oC\pm2^oC$) and ambient temperature ($25^oC\pm2^oC$) using split plot experimental design with three replicates. Results showed statistically significant variations for $KMnO_4$ concentrations as well as for temperatures on different parameters of banana. Fruits treated with 1% $KMnO_4$ concentration at low temperature improved most of the quality parameters; weight of fruit after ripening (78.81g), pH (6.5), TSS (19.8 ^{o}Brix), fruit pulp (73.05 g), while, change of peel color at stage-6 took many days (15.08) and increased the shelf life (19.51 days) as compared to other $KMnO_4$ Concentrations. However, the lowest quality and shelf life were observed under 3% $KMnO_4$ concentration and control. Minimum ethylene gas was noted in banana fruits treated with 1% of $KMnO_4$ (0.8, 10^{-1} μL. L^{-1}. h^{-1}. Kg^{-1} FW) at low temperature reflected by various physicochemical parameters observed.

Keywords

Banana, $KMnO_4$, TSS, Temperature, Shelf life, and Ethylen

1. Introduction

Banana (*Musa paradisiacal* L.) fruit of musaceae family is one of important fruits in Pakistan. In terms of food security for rural villages, banana becomes important food compared to food derived from roots and tuber because it is available throughout the year [1-2]. Banana has no indication to cause allergy, easy to serve and rich of vitamins and minerals. Since the production area is patchy among farmer's lands and among regions, postharvest loss is high, ranging of 20-30%. Banana is a climacteric fruit as indicated by marked increase of respiration rate and ethylene production during ripening process [3], causing low storage ability under normal condition. Banana easily deteriorates as indicated by changing of peel color, loss of weight, and lost firmness a few days after harvesting. Enhancement in banana quality, application of postharvest treatment is very important [1-2].

More research is to be conducted to increase storage period basically using ethylene absorber, where potassium permanganate ($KMnO_4$) is effective compared to commercially ethylene binders CaO and $CaCl_2$ [4-5]. Application of $KMnO_4$ as ethylene absorber significantly inhibited banana yellowing, maintained flavor by up to 15 days under ambient temperature (28^oC) and prolonged the shelf life of the fruit by up to 45 days at 13^oC [6-7]. $KMnO_4$ in both forms, absorbed in filter paper or granules, in combination with perforated polyethylene lining reached the maximum TSS value six and eight days later, respectively, compared to the untreated fruits. $KMnO_4$ in filter paper or granules with sealed polyethylene films reached the maximum TSS value [9]. For storage in banana, direct application of $KMnO_4$ solution is not desirable because it tints peel color into blue, therefore, $KMnO_4$ is applied within a carrier. Carrier which has low density, low absorbent, and inert to $KMnO_4$ is highly recommended for banana [8]. For small scale farmers, the carrier should be available in local markets, abundant and low cost preferably cheap. Many materials have been evaluated such as charcoal, floating stone and sawdust [9-10], and zeolite [11-6] to prolong banana storage. Using zeolite as carrier of $KMnO_4$ banana quality was kept 7 days longer compared to the control. Zeolite as $KMnO_4$ carrier had a similar effectiveness to the commercial ethylene binders; however, a slight delay in color change was also observed in banana fruits kept in polyethylene bag with inclusion of $KMnO_4$ which could be attributed to its ethylene absorbing capacity [12-13].

Fruit placed in an open air is an indication of high respiration rate and ripening thereby resulting in quality deterioration with the onset of senescence. Refrigeration is one of the most important methods used to delay the processes of senescence. When combined with modified atmosphere, it causes ripening delay and keeps fruit according to market needs [14-15]. During storage under tropical climates with relatively higher ambient temperatures, bananas ripen fast and shelf life is shorter ambient temperature. The low storage of banana ensures extended shelf life [5-16].

Banana is a climacteric fruit as indicated by marked increase of respiration rate and ethylene production during ripening process. causing low storage ability under normal condition. Banana easily deteriorates as indicated by changing of peel color, loss of weight, and lost firmness a few days after harvesting.

Keeping in view the significance of banana low shelf life, the present study was carried out to enhance the overall quality and shelf life of banana using potassium permanganate ($KMnO_4$) as ethylene absorbent at different temperatures. To find out the most appropriate concentration of $KMnO_4$ with temperature on the basis of quality and shelf life of banana.

2. Materials and Methods

Present research was conducted during 2019. The well matured banana hands (Vr. Basrai) of stage-1 (green) as per recommended banana chart (chart-1) were harvested from a commercial grower's orchard of Tandojam. The harvested fruit bunches were brought to the postgraduate laboratory, Department of Horticulture, Sindh Agriculture University Tandojam. The hands from bunches were separated and then fully matured individual fingers were separated from the hands, removed dust with soft tissue papers. The treatment factors were as **Factor-A:** Temperatures (T) = 02 (T_1=25$^oC\pm2^oC$ (Ambient temperature) and T_2 = 7$^oC\pm2^oC$ (Low temperature), **Factor-B:** Potassium permanganate ($KMnO_4$ = 04 concentrations (KM_1 = 0%, KM_2 = 1%, KM_3 = 2%, KM_4 = 3%), replicated three times in Split plot design.

2.1 Preparation of Potassium Permanganate ($KMnO_4$) Solution

The solution of $KMnO_4$ was prepared as per the concentrations mentioned in the treatments plan. 1 g of potassium permanganate $KMnO_4$ was weighted on weighing balance machine then dissolved in 100 ml of distilled water. 10 g of saw dust was mixed into the solution which was kept for 24 hrs at ambient temperature so that saw dust can absorb the solution well. After 24 hours of addition, sachets of muslin cloth bag (15 cm^2) containing 20 g of sawdust impregnated with $KMnO_4$ were prepared and inserted safely in polyethylene bags containing banana fruit along with 40 pellets of silica gel sachets in each treatment. Each transparent polyethylene bag comprised of five fingers. Each treatment had three polyethylene bags (15 fruits of stage -1) fruit weight before ripening was noted before treatment application. Then two sets of each $KMnO_4$ concentrations were prepared. One set of treatment was subjected at ambient temperature conditions and the other set was placed in a refrigerator at low temperature 7°C ± 2°C. Following quality parameters were taken as the banana finger becomes ripened. Banana fruits were observed daily for ripening and diseases purpose. Silica gel sachets were added in each polyethylene bags as desiccators [9].

Observations recorded during our research studies were, weight of fruit before ripening (g), days to change of peel color, weight of fruit after ripening (g), weight of pulp (g), total soluble solids (°Brix), fruit pH and shelf life (days).

2.2 Weight of fruits before ripening (g)

Before packing the fruits for treatments, the weight of average fruits was recorded for individual fingers using electronic weighting balance machine in grams then averages were calculated for treatment means.

2.3. Days to change of peel color

The days from the date of storage up to the date of peel color change in each banana finger for all the treatments were noted as per standard banana color chart visually and recorded, accordingly the averages was worked out.

2.4 Weight of fruits after ripening (g)

When the experimental fruits in different treatments reached to the ripening stage, they were weighted individually by means of electronic weighing balance machine in grams then averages were calculated.

2.5 Weight of Pulp (g)

At ripening, the peel from each of the experimental fruit finger was separated from the pulp and the pulp was subjected to weight in grams by using electronic weighting balance machine and averages were worked out.

2.6 Total Soluble Solids (°Brix)

The total soluble solids (TSS°Brix) were determined by using hand refractometer (Shibuya optical co., Ltd Japan). After cleaning, the equipment was adjusted to zero using distilled water. Then a certain quantity of prepared solution of banana pulp was dropped on the Prism-plate of the refractometer and lid was placed over to cover it. The reading for total soluble solids was recorded.

2.7 Fruit pH

The pH values of the fruit pulp were determined by using pH meter (Hana Instrument, HI8417, Italy). pH was determined as the fingers became ripened. 5g of fruits pulp was meshed then 50 ml of distilled water was added to make a uniform fruit concentration. Before inserting into the sample pH meter was caliber at 4 and 7 reading then inserted into the samples. Each time the pH rod was washed off with distilled water.

2.8 Shelf life (days)

The shelf life is the postharvest period of ripe banana fruits during which their quality deterioration is not started and these are acceptable for human consumption. The shelf life on the basis of chemical analysis for fruit quality deterioration was recorded in days and averaged. Shelf life was measured as per banana color chart of stage-6 (Chart-1).

2.9 Ethylene Emission/(10^{-1} µL. L^{-1}. h^{-1}. Kg^{-1} FW)

A gas chromatography and headspace solid-phase microextraction (HS-SPME) method was used for investigating ethylene emission (). Ethylene gas was measured with protocol [17-18] of a gas chromatograph (GC) with a flame ionisation detector (FID) containing a 2–3-L jar with a banana sample at (25 ± 0.5)°C, acetylene gas was used to inject ethylene with a 250-µL glass syringe and a 50-mL plastic syringe including a test tube. Before measurements banana samples were stored at 12°C for 48 hours to stop the ripening inhibitors. Banana was weighted and placed into the jar to measure the volume of air in the container (Jar was filled with water and volume of water was noted). To initiate ripening, injected approximately the equivalent of 10,000 µL·L–1 of acetylene or propylene with a 50-mL plastic syringe through the septum. The jars with bananas were stored at 25°C and 10°C (ambient and low temperature for fruit ethylene synthesis). Taking 250 µL from the head-space of jar air and inject it into the GC column, erate the jars (leave them open for a few minutes), reseal the jars and store them again at 25 °C for further measurement, after each measurement, calculate the amount of ethylene produced.

2.10 Statistical analysis

The collected data was subjected to statistical analysis using Statistics 8.1 computer software [19]. Duncan's multiple range test ($P < 0.05$) was applied to compare treatments superiority at 5% probability level.

3. Results

3.1 Fruit weight (g) before ripening

Fruits at random were selected for treatment applications. Fruits were them weighted on first day and then subjected to treatments. This table has been given as different fruits have different weight therefore, only average has been presented in Table 1 to justify Table 3 fruit weight after treatments.

3.2 Days to peel color change at stage-6

It is evident from the results (Figure 2) that the banana fruit in storage of low temperature for ripening took maximum days to change peel color stage-5 under the treatment comprised of potassium permanganateat 1% concentration. The interactive effect of potassium permanganate and température condition show fruit start to ripen rapidly at 2.37 days at ambient température storage ($25^oC±2^oC$) without adding potassium permanganate; while the banana fruits changed peel color in maximum number of days (15.80) when fruits were treated with potassium permanganate 1% concentration at low temperature storage $7^oC±2^oC$. It was observed that the effect of potassium permanganate concentration on the days to peel color change in banana was variable; when there was no potassium permanganate treatment and only was used, the peel color change occurred earliest while this process delayed greatly when potassium permanganate at 1% concentration was used for treatment. However, there was an inverse effect on days to peel color change later and with increasing the potassium permanganate concentration from 2% to 3% the days to peel color changed were decreased. This suggested that at low storage temperature 7^{o}C±2^{o}C, the fruit ripening process delays and takes manifold time to reach at the peel color change stage-5 of fruit over ambient temperature storage.

3.3 Weight of fruit after ripening (g)

The fruit weight of banana during storage for ripening is of major concern, because the fruit quality may vary in response to the storage temperature. Moreover, the interactive effect of Potassium permanganate and storage conditions may also change the physical fruit quality during storage for ripening. Potassium permanganate × storage conditions showed significant results ($P<0.05$) on the weight of banana fruits after ripening; The data (Figure 3) exhibited that the banana fruit weight after ripening was relatively higher (80.13 g) when treated with potassium permanganateat 1% concentration at low temperature (7^{o}C±2^{o}C), followed by average fruit weight after ripening of 78.81 g at low temperature (7^{o}C±2^{o}C) without $KMnO_4$ treatment whereas, fruit weight decreased as the potassium permanganate concentrations increased from 2% to 3%, respectively. However, lowest fruit weight (62.73 g) after ripening was observed when treated without potassium permanganate at ambient températures (25^{o}C±2^{o}C).

This showed that at ambient temperature, the moisture evaporation took placed for which the fruit weight was lost considerably; while at low temperature conditions, the fruit weight loss was minimal due to less production of ethylene gas and less humidity at low temperature. The effectiveness of potassium permanganate on the weight of banana fruit after ripening showed a linear trend and at 1% concentration the fruit weight after ripening remained highest which decreased with each increasing unit in the potassium permanganate concentration and reaching to the lowest fruit weight when treated with highest concentrations (3%). However, a vital effect on weight of fruit gain after ripening was detected on the part of low temperature; where the fruit at low temperature gained markedly higher weight as compared to the fruits at ambient temperature storage.

3.4 Pulp weight (g)

In banana fruit, after removing peel the whole fibrous material is called the banana pulp and primarily the market quality is based on the pulp quality after ripening. The pulp weight of banana during storage for ripening may vary due to storage temperature as well as the treatment for ripening. The effect of different concentrations of potassium permanganate on the pulp weight of banana fruit under two storage temperatures was determined (Figure 4). Interactive effect of potassium permanganate × storage temperature conditions was statistically significant ($P<0.05$) on the pulp weight. Results show maximum pulp weight 75.40 g has been recorded where, banana fingers have been treated to 1% potassium permanganate at low temperature (7^{o}C±2^{o}C) followed by 73.05 g under 2% potassium permanganate, while the pulp weight was minimum (48.13 g) when kept at ambient temperature (25^{o}C±2^{o}C) without potassium permanganate. The results showed that increased concentrations of potassium permanganate (1%-3%) at ambient temperature increased pulp weight (65.73-57.23 g); while at low temperature potassium permanganate treatment 1% to 2% caused a gain in pulp weight and increasing concentration 3% showed a simultaneous decrease in pulp weight 65.32 g. The study showed that under low temperature, pulp weight was considerably increased. Low temperature has been considered good for banana as a climacteric fruit of subtropical regions.

3.5 Fruit pH

Results pertaining to fruit pH (Figure 5) revealed statistically significant results for banana fruit. The fruit pH of banana during storage is influenced by a number of factors including storage temperature and treatment for ripening. The impact of various concentrations of potassium permanganate on the fruit pH of banana under varied storage temperatures was determined Neutral pH 6.76 have been observed in banana kept at low temperature (7^{o}C±2^{o}C) and treated with 1% potassium permanganate this result is nonsignificant to fruits kept at ambient conditions which had fruit pH of 6.57 with 1% potassium permanganate. Both temperatures without potassium permanganate showed an acidic pH of fruit 4.34 to 4.34.

The fruit pH of banana under different storage temperatures showed that pH was significantly higher (5.43) for fruit kept in low storage (7^{o}C±2^{o}C) as compared to fruit pH level of 5.68 under ambient temperature (25^{o}C±2^{o}C). This showed that under ambient temperature, the banana fruits were not physiologically changed; while under low storage, chemical changes were reflected by increasing fruit pH. The interactive effect of potassium permanganate and temperature showed fruit pH was neutral (6.66) with 1% potassium permanganate under low temperature (7^{o}C±2^{o}C); while the fruit pH was acidic (4.28) when treated with kept under ambient temperature (25^{o}C±2^{o}C). The results showed that regardless the storage conditions, the fruit pH was lowest when the fruits were not treated with potassium permanganate was used; while the fruit pH was highest under both the temperatures under 1% concentration of potassium permanganate and increasing concentration of potassium permanganate showed a simultaneous decrease in fruit pH.

3.6 Total soluble solids (°Brix) in fruit (%)

The changes may occur in total soluble solids or °Brix of the fruits like banana during ripening process and storage conditions; while the effect of treatment during ripening and storage has also been well recognized. The effect of various concentrations of potassium permanganate on the total soluble solids in fruit of banana under varied storage temperatures was analyzed and the results are produced in Figure 6.

It is evident from the results (Figure 6) that the total soluble solids content was highest (17.34%) in fruits treated with potassium permanganate at 1% concentration, followed by 12.31 and 9.92% total soluble solids in fruits treated with potassium permanganate at 2% concentration and 3% concentration, respectively. However, the lowest content of total soluble solids (7.11%) was determined in fruits kept untreated for potassium permanganate was used.

The total soluble solids in banana fruit under different storage temperatures indicated that significantly higher total soluble solids (10.04%) was determined in low storage fruits (7°C±2°C) as compared to 13.30% total soluble solids in fruits under ambient temperature (25°C±2°C). This showed that apart from the ripening process, no distinctive change in the chemical composition was occurred in fruits under ambient temperature; while in fruits storage in low storage considerable chemical changes including increase in total soluble solids were determined. The interactive effect of potassium permanganate× Storage temperature showed that the total soluble solids in fruit was maximum (19.80%) 1% potassium permanganate and at low temperature (7°C±2°C); while the total soluble solids in fruit was minimum (6.13%) when treated with under ambient temperature (25°C±2°C). It was observed that regardless the storage conditions, the total soluble solids in banana fruits was lowest when the fruits were kept untreated of potassium permanganate; while regardless the storage temperature, the total soluble solids were highest when fruits were treated with 1% concentration of potassium permanganate and increasing concentration of potassium permanganate caused a concurrent reduction in total soluble solids.

3.7 Shelf life (Days)

The shelf life is the postharvest period in fruits during which their quality deterioration is not started and these are acceptable for human consumption. The shelf life is ultimately most important characteristics for storage fruits and most of the treatments are considered on the basis of shelf life of the fruits and their products. In this study the shelf life of storage banana under the effect of different concentrations of potassium permanganate and storage temperature (Figure 7). The results in Table 7 indicated that the maximum shelf life (13.81 days) was observed in banana fruits treated with 1% potassium permanganate concentration, and the shelf life reduced to 10.90 and 9.41 days under 2% and 3% potassium permanganate concentrations, respectively; while the shelf life decreased to lowest (7.27 days) when banana fruits were kept untreated for potassium permanganate.

Effect of potassium permanganate in response to temperature conditions on shelf life exerted a great effect. Maximum shelf life (19.51 days) was observed where banana fruits treated by1% potassium permanganate at low temperature (7°C±2°C) while shelf life reduced (3.34 days) when fruits were not treated with potassium permanganate at ambient temperature conditions (25°C±2°C). It was observed that potassium permanganate treatment was highly beneficial for increasing the shelf life of banana regardless at low temperature. However, potassium permanganate at 1% concentration was the most effective storage banana treatment, but the shelf life decreased with increasing the potassium permanganate concentration over 1%.

3.8 Ethylene emission/(10^{-4} μL. L^{-1}. h^{-1}. Kg^{-1} FW)

Release of ethylene during treatments showed that $KMnO_4$ concentrations and temperature produced statistically a significant effect on the production of ethylene in banana fruits treated with $KMnO_4$ concentrations under low temperature of 7±2°C. Minimum ethylene gas was noted in banana fruits treated with 1% of $KMnO_4$ (0.8×10^{-4} μL. L^{-1}. h^{-1}. Kg^{-1} FW) on alternate day till the end of shelf life at low temperature. Fruits kept at ambient temperature accelerated the ethylene production in banana which were not treated with $KMnO_4$ (9.8×10^{-4} μL. L^{-1}. h^{-1}. Kg^{-1} FW). However, fruits treated with $KMnO_4$ concentrations produced less amount of ethylene as compared to the control. Minimum ethylene gas at ambient temperature was produced in fruits treated with 1% $KMnO_4$ (4.3×10^{-4} μL. L^{-1}. h^{-1}. Kg^{-1} FW) followed by 2% $KMnO_4$ concentrations. At 3% $KMnO_4$ concentrations ethylene production showed an increase trend under both the temperatures. However, low temperature greatly reduced the ethylene production as compared to the ambient temperature.

4. Discussion

Fruit quality is much influenced by its surrounding environments, especially temperature which accelerates the ripening process of climacteric fruits. In the present study $KMnO_4$ and temperature conditions as well as interactive effect on the days to peel color change was statistically significant ($P < 0.05$). The banana fruit kept at low temperature with $KMnO_4$ at 1% concentration improved all the quality traits and shelf life while banana fruits kept at ambient temperature treated with $KMnO_4$ at 0% impaires fruit quality. The effect of $KMnO_4$ concentration on the days to peel color change in banana was variable; when there was no $KMnO_4$ treatment, the peel colour change occurred earliest while this process delayed greatly when $KMnO_4$ at 1% concentration was used for treatment. However, there was an inverse effect on days to peel color change later and with increasing the $KMnO_4$ concentration, the days to peel color changed were decreased. Further, banana stored under low temperature delayed the peel color change; while early peel color change was recorded when banana was kept under ambient temperature for ripening. Banana ripening treatment with $KMnO_4$ significantly affected the fruit peel color change; while the effect of temperature on the days to peel color change was also remarkable [5]. Marked variation in peel color development period during storage of bananas was noticed due to temperature [12-20].

The temperature and its interactive effect of $KMnO_4$ showed significant impact ($P<0.05$) on the weight of banana fruits after ripening. The fruit weight after ripening was relatively higher when treated with $KMnO_4$ at 1% concentration and lowest when treated with $KMnO_4$ at 3% concentration. The fruit weight was significantly higher for banana kept under ambient temperature as compared to fruit when kept in low storage. In low storage, the moisture evaporation takes place and the fruit weight was lost considerably; while under ambient temperature conditions, the fruit weight loss was minimal. The effectiveness of $KMnO_4$ on the weight of banana fruit after ripening showed non-linear trend and at 1% concentration the fruit weight after ripening remained highest which decreased with each decreasing unit in the $KMnO_4$ concentration and reaching to the lowest fruit weight when treated with highest concentrations (3%). However, a vital effect on weight of fruit after ripening was detected on the part of storage temperature; where the fruit under low storage temperature lost markedly higher weight as compared to the fruits under ambient temperature storage. These results are in agreement with those of [20] who reported that the fruit weight was significantly affected by the storage temperature; while a significant effect of ripening treatment and temperature was noticed on fruit weight [21] was recorded. Similarly, Thompson et al. [16] concluded that fruit weight, in stored banana for ripening was better in taste and flavor with addition to chemical characteristics in treated fruits. Mae et al. [12] reported that $KMnO_4$ treatment and temperature significantly affected the fruit weight of ripening banana.

The effect of temperature with $KMnO_4$ was statistically significant ($P<0.05$) on the pulp weight; while the effect of different concentrations of $KMnO_4$ on pulp weight was statistically non-significant ($P>0.05$). The pulp weight was comparatively higher when treated with $KMnO_4$ at 1% concentration while lowest when storage banana was treated with $KMnO_4$ at 3% concentration. The pulp weight was significantly higher for banana stored at ambient temperature as compared to pulp weight stored at low temperature. The results of the present research are in accordance with Lobo et al. [11]; Akhter et al. [15] and Mae et al. [12]**.** The fruit pH was significantly ($P<0.05$) affected by $KMnO_4$ treatment and storage temperature while the interactive effect of $KMnO_4$ with storage temperature on fruit pH was non-significant ($P>0.05$). The fruit pH was highest when treated with $KMnO_4$ at 1%+ lowest when storage banana was kept untreated for $KMnO_4$. The pH was significantly higher for fruit kept in low storage as compared to fruit pH level of under ambient temperature. Under ambient temperature, the banana fruits were not physiologically changed; while under low temperature, chemical changes were reflected by increasing fruit pH. The fruit pH was highest under both the temperatures under 1% concentration of $KMnO_4$ and increasing concentration of $KMnO_4$ showed a simultaneous decrease in fruit pH. These results are in concurrence to those of Deka et al. [13] and Chauhan et al. [22] who reported that the storage treatment of banana results in fruit pH value of 5.13. The pulp firmness was also acceptable in the treated banana as compared to control temperature.

The contents of total soluble solids in banana was significantly influenced ($P<0.05$) by $KMnO_4$ treatment, storage temperature as well as by $KMnO_4 \times$ storage temperature interaction. The total soluble solids content was highest in fruits treated with $KMnO_4$ at 1% concentration and lowest in fruits kept untreated for $KMnO_4$ was used. Significantly, higher total soluble solids were determined in low storage fruits as compared to total soluble solids in fruits under ambient temperature. This showed that apart from the ripening process fruits stored at low temperature distinctive considerable chemical changes in total soluble solids were determined. The total soluble solids in banana fruits were lowest when the fruits were kept untreated of $KMnO_4$ and only Silica gel was used; while regardless the storage temperature, the total soluble solids were highest when fruits were treated with 1% concentration of $KMnO_4$ and increasing concentration of $KMnO_4$ caused a concurrent reduction in total soluble solids. The results for total soluble solids achieved in this study are further confirmed by a number of past workers. Silva et al. [23] reported that the banana fruits treated for ripening with $KMnO_4$ at 2 g per bag, bags sealed and stored at 10.4±0.9°C were determined for TSS up to 10.8 ^{0}Brix. Santosa et al. [24] reported that TSS in ripe banana at 12 DAT with $KMnO_4$ was 25.25±0.98%. Mae et al. [12] reported that potassium permanganate resulted in higher TSS accumulation during storage of bananas. Zewter et al. [25] examined the effect of storage temperature and fruit treatment for ripening and concluded that TSS with $KMnO_4$ treatment was 21.5 at 16 days of storage. Akhter et al. [15] reported that maximum value of TSS (27.11% (^{o}Brix) was observed at the 6th day of storage under control condition with $KMnO_4$ treatment. Lobo et al. [11] reported that under all ethylene concentrations at 12°C temperature showed uneven ripening; while at ripening temperature of 15°C and storage temperature of 20°C the shelf life prolonged up to three days. These differences were accompanied by changes in the respiration pattern of the bananas, their quality parameters (TSS, peel and pulp firmness) and their soluble sugars and organic acids composition. Lima et al. [10] reported that there was reduction in soluble solids for ripe fruit under ambient temperature and (11.33%) when compared with low storage (16.77%). Ahmad et al. [14] reported that ripening speed of small and large size banana was also not affected by the treatment; but the total soluble solids were markedly higher 22.7% and 22.6% in small size banana fruits as compared to 22.0 and 21.7% in large size banana fruits under experiment under 16°C and 18°C temperatures for ripening storage.

The shelf life indicated that the shelf life of storage banana was significantly ($P<0.05$) affected by different concentrations of $KMnO_4$, and temperature. In low temperature maximum shelf life was recorded as compared to banana kept under ambient temperature. This suggested that in low storage, the shelf life of fruit is prolonged manifold as compared to the fruits kept under ambient temperature. The $KMnO_4$ treatment was highly beneficial for increasing the shelf life of banana regardless the storage temperature. However, $KMnO_4$ at 1% concentration was the most effective storage banana treatment in addition; but the shelf life decreased with increasing the $KMnO_4$ concentration over 1%. These results are in line with those of Chuhan et al. [22] who evaluated the synergistic effect between modified atmosphere and potassium permanganate on ripening behavior of unripe banana fruits at 13^{o}C followed and reported shelf life extension to 15, 24 and 32 days, respectively at different KMnO4 concentrations as against shelf life of 12 days of control. $KMnO_4$ application in combination with soda lime as CO_2 scrubber further enhanced the shelf life of 18, 28 and 36 days under different types of modified atmosphere packing. Sugri and Johnson (5) reported that use of KMnO4 increased green life by 3 to 6 days across treatments [1].

Previous studies on ethylene inhibitors have declared that it is directly related with the growth of fruits (1-3-7-25-). Thus, the biosynthesis and accumulation of aroma components are directly related to the production of ethylene in fruits. As shown in Figure 8, firstly, ethylene has gradually risen at ambient temperature while, at low temperature its rise up is at slow level, whereas, the ethylene inhibitor potassium permanganate ($KMnO_4$) also exhibited a positive influence to control it.

Tan [7] argued that application of potassium permanganate in polyethylene bags can extend the postharvest life of banana fruit under ambient temperature and chill storage condition. However, attention must be paid to chill storage because banana fruits are sensitive to low temperature, and can cause chilling injury if kept below 12ºC. Similarly, Mae et al. [12] reported that potassium permanganate resulted in more delay of fruit ripening and extension of shelf life of banana fruits. From another study, Akhter et al. [15] found that postharvest treatments exerted significant effects to extend shelf life of bananas. The longest shelf life of 15.58 days was observed in bananas held at 15^{o}C temperature. Lobo et al. [11] agreed that shelf life of ethylene-treated bananas could reliably be modulated within the range of 6 to 12 days, without any decrease in fruit quality, just by adjusting exposure to ethylene and storage temperature.

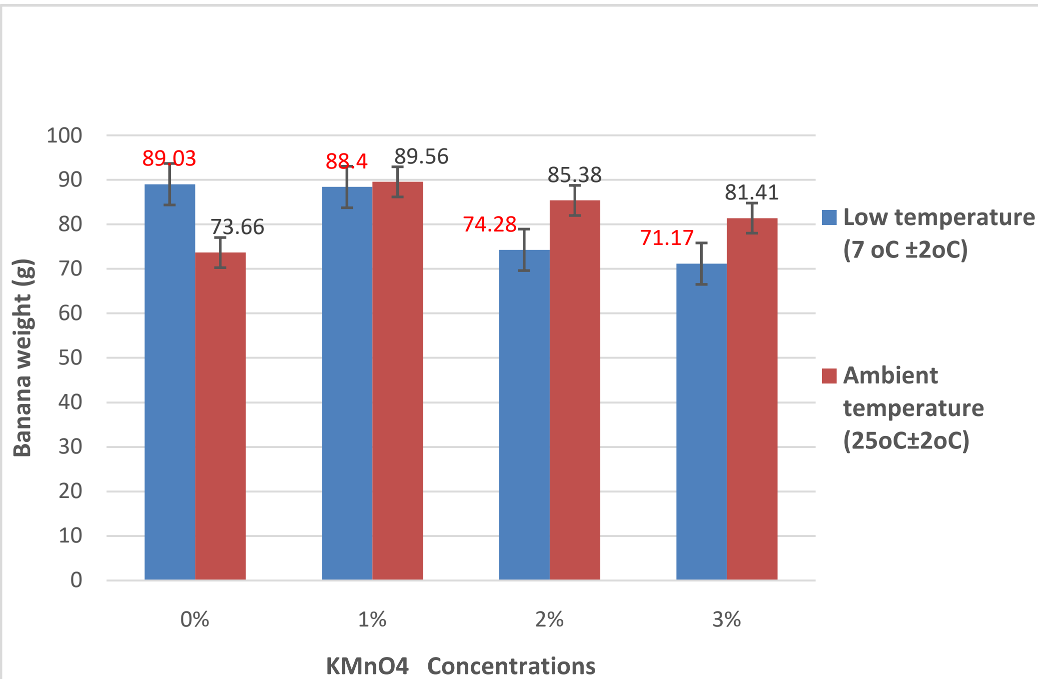

Figure 1. Banana fruit weight (g) before ripening and treatment application of potassium permanganate ($KMnO_4$) and temperatures. As fingers in a bunch at green stage are having different weights so immediately after harvest each finger was cut, labeled for treatments and weighted individually.

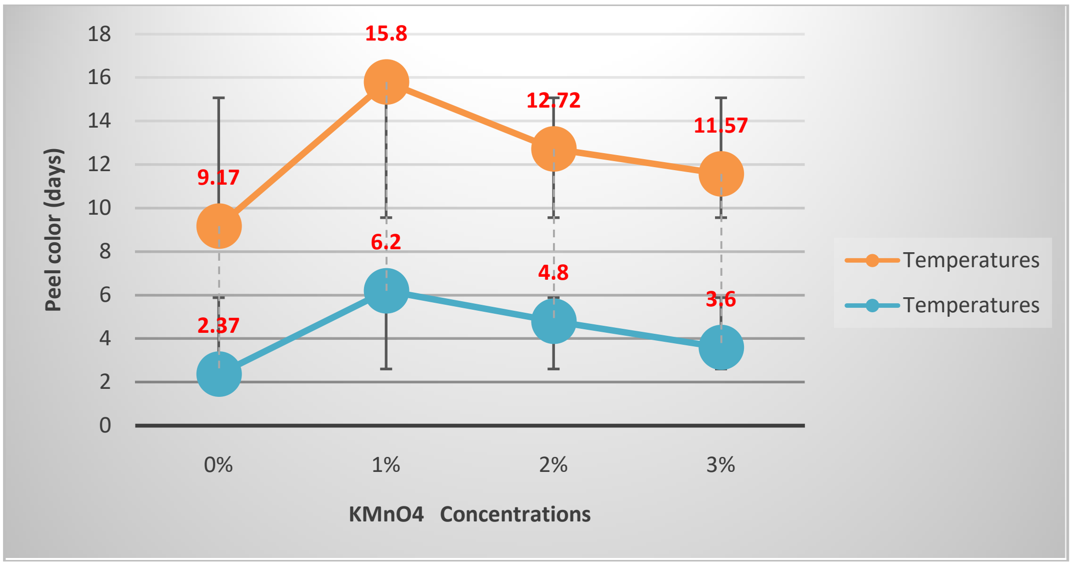

Figure 2. Change of banana peel color (days) under application of potassium permanganate ($KMnO_4$) concentrations and temperatures on the basis of banana color chart.

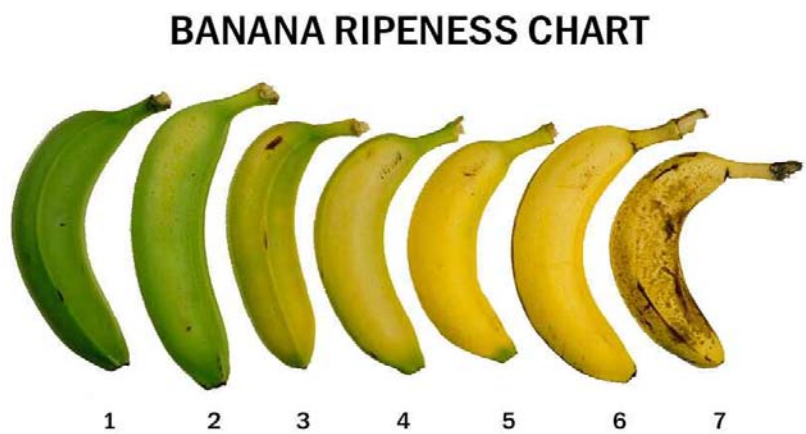

Chart 1. Banana chart showing ripeness stages from 1 to 7 (unripened to fully ripened) on the basis of shape and color.

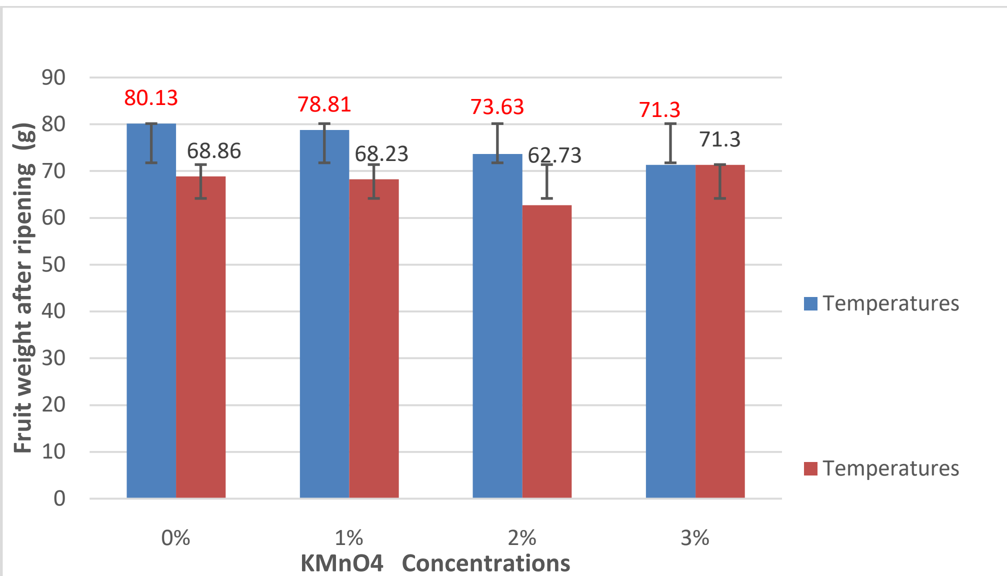

Figure 3. Banana fruit weight (g) after ripening under application of potassium permanganate ($KMnO_4$) and temperatures.

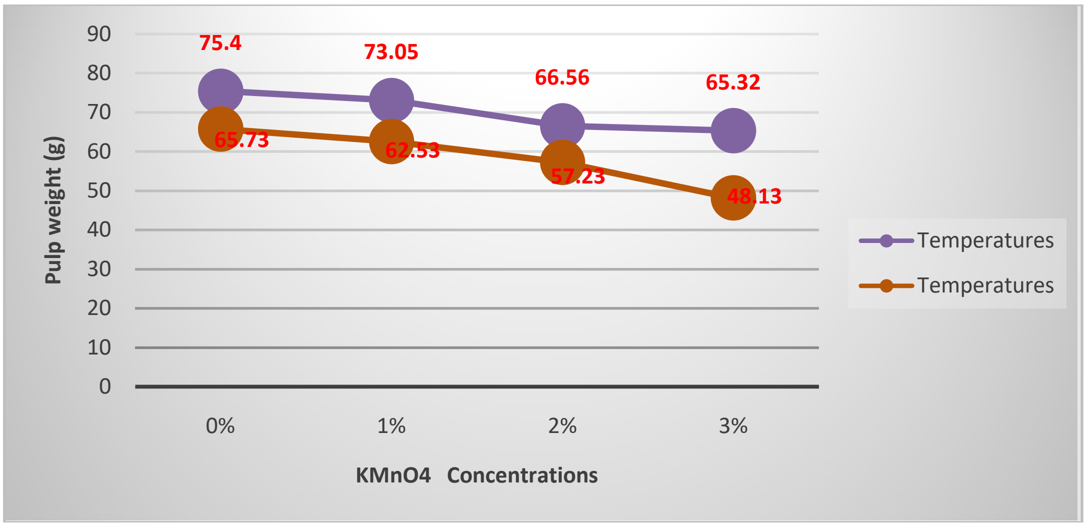

Figure 4. Banana pulp weight (g) under concentrations of potassium permanganate ($KMnO_4$) and temperatures.

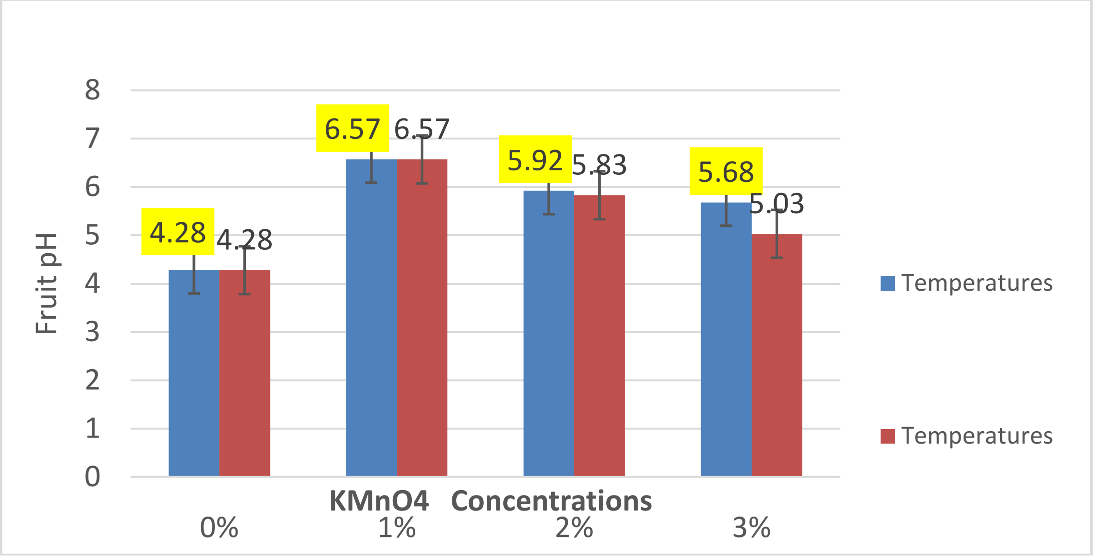

Figure 5. Banana fruit pH under concentrations of potassium permanganate ($KMnO_4$) and temperatures.

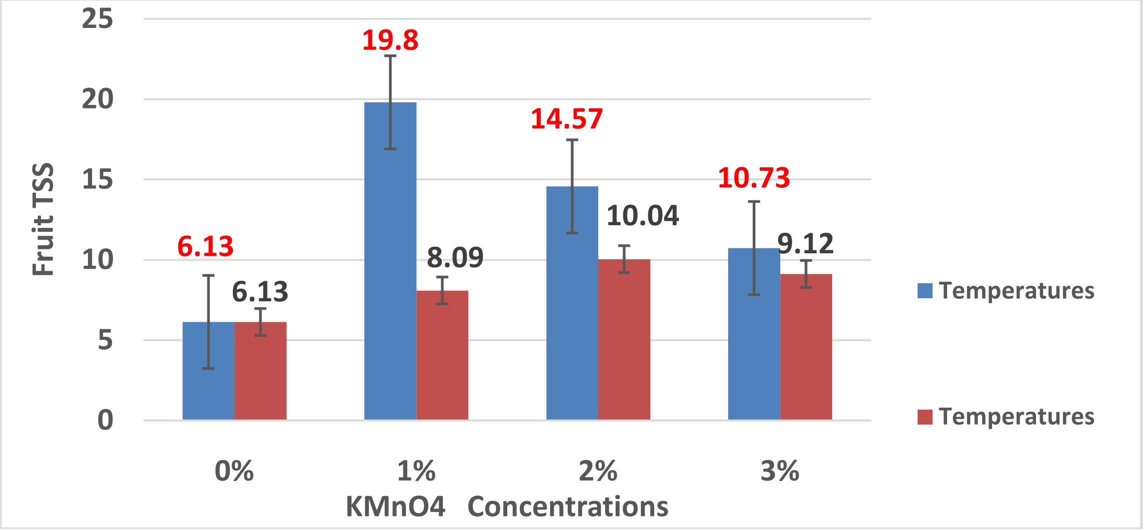

Figure 6. Banana fruit TSS (^{o}Brix) under concentrations of potassium permanganate ($KMnO_4$) and temperatures.

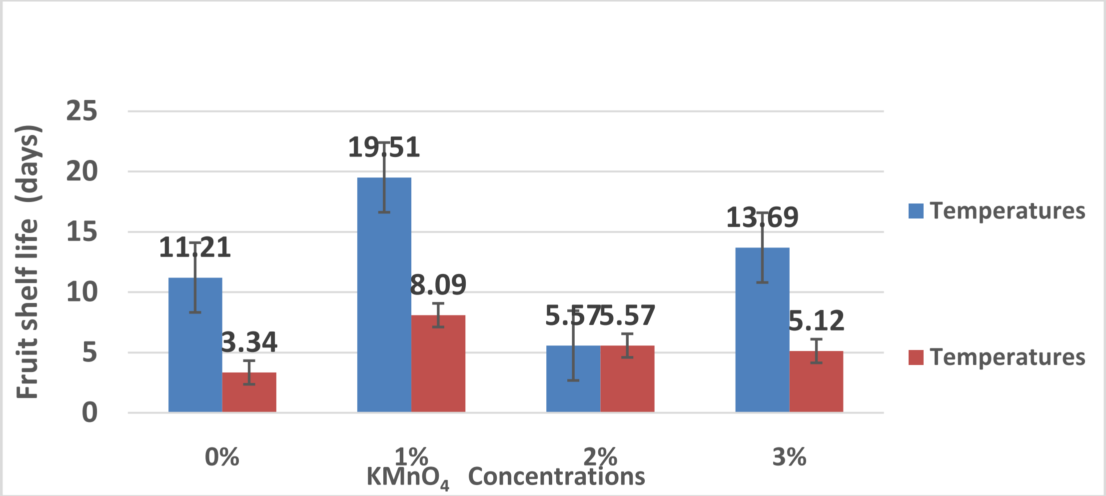

Figure 7. Shelf life of banana (days) under concentrations of potassium permanganate ($KMnO_4$) and temperatures.

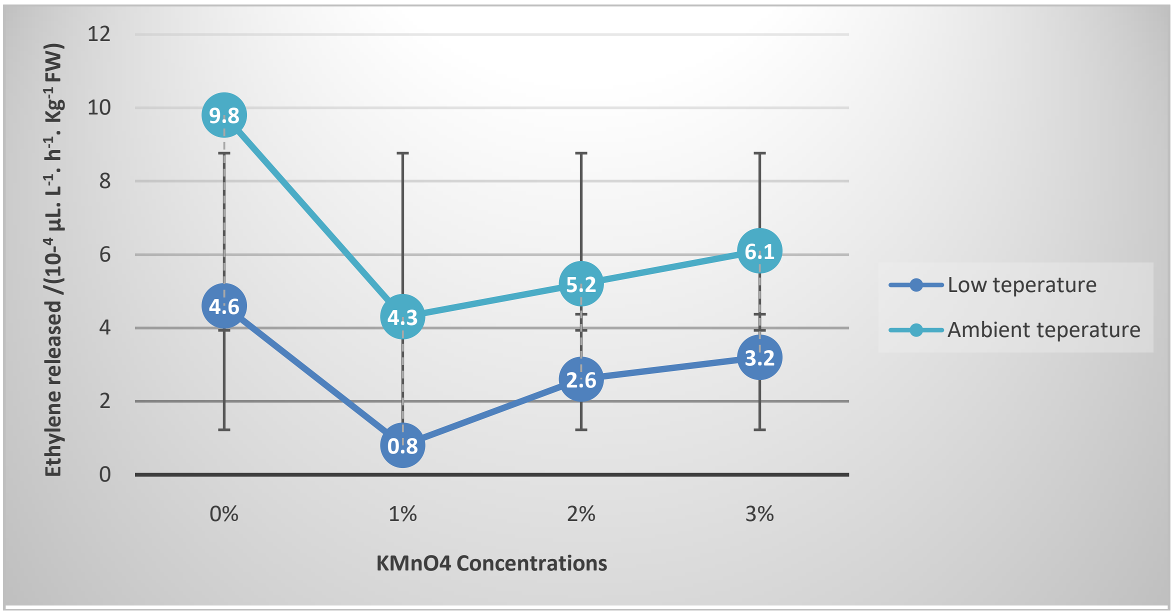

Figure 8. Ethylene Emission in banana/(10^{-4} µL. L^{-1}. h^{-1}. Kg^{-1} FW) under concentrations of potassium permanganate ($KMnO_4$) and temperatures.

5. Conclusion

Present study concluded that overall quality and shelf life of banana for 20 days enhanced when banana was treated with 1% $KMnO_4$ concentration under low temperature storage condition, were found qualitatively superior over ambient temperature which was reflected by various physicochemical parameters observed. Therefore, this can be used as a nondestructive and low input storage technique that can benefit farming community and wholesalers.

References

[1] Illeperuma, C. K. and Jayasuriya, P. (2002). Prolonged storage of ‘Karuthacolomban’ mango by modified atmosphere packaging at low temperature. *J. Hort. Sci. Biot.*, **77**, 153-157.

[2] Chitarra, M. I. F. and Chitarra, A. B. (2005). Postharvest fruits and vegetables: physiology and handling. 2nd ed. rev. ampl. Lavras. Ufla. 2nd.ed. Rev. Ampl. Lavras. Ufla., p.783.

[3] Calberto, G., Staver, C., Etten, J. V., and Molina, A. B. (2012). Banana growers facing climate change in Asia and the Pacific: Planning adaptation to uncertainty, weather variability and extreme events. *International banana symposium.*, p. 13, Kaohsiung city, Taiwan, Republic of China.

[4] Sambeganarko, A. (2008). Effect of $KMnO_4$, *Ethylene Absorber*, and $CaCl_2$ on quality and storage of banana var. Raja Bulu

(*Musa paradisiaca* L.).Undergraduate Thesis, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. Bogor, Indo., p. 40.

[5] Sugri, I. and Johnson, P. N. T. (2009). Effect of two storage methods on the keeping and sensory qualities of four plantain varieties. *A.J.F.A.N.D.*, 9, 1091-1101.

[6] Sholihati. (2004). Studies on potassium permanganate absorbent to prolong storage banana varRaja (*Musa Paradisiaca*var. *sapientum*L.). Thesis, Graduate School, Faculty of Agriculture, Bogor Agricultural University. Bogor, Indo., p. 177.

[7] Tan, Y. M. (2009). Effect of ethylene absorber, and temperature on banana shelf life. *J. Amer. Soc. Hort. Sci.*, 129, 445-456.

[8] Kader, A. A. (2002). Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources, 3rd edition. Publication 3311.

[9] Jannah, U. F. (2008). Effect of potassium permanganate absorber on storage of banana var. Raja Bulu. Undergraduate Thesis, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. Bogor, Indo., p.48.

[10] Lima, O. S., Souza, E. G., Amorim, E. P., and Pereira, M. E. C. (2014). Ripening and shelf life of 'BRS Caipira' banana fruit stored under ambient temperature or refrigeration. *Cienc. Rural*, 44, 45-52.

[11] Lobo, M. G., Gonzalez, M., Pena, A., and Marrero, A. (2013). Effects of Ethylene Exposure Temperature on Shelf Life, Composition and Quality of Artificially Ripened Bananas (*Musa acuminata* AAA, cv. 'Dwarf Cavendish'). *Investigaciones Agrarias*, 3, 82-90.

[12] Mae, A., Elamin, A., Abu-Bakr, and Goukh, A. (2012). Effect of polyethylene film lining and potassium permanganate on quality and shelf-life of banana fruits. *Gezira J. Agri. Sci.*, **7**, 217-230.

[13] Deka, B. C., Choudhury, S., Bhattacharyya, A., Begum, K. H., and Neog, M. (2013). Postharvest treatments for shelf life extension of banana under different storage environments. *Proc. Int. Conf. Managing quality in chains-The Integrated view on fruits and vegetables quality. ISHS Acta Horti*, p. 712.

[14] Ahmad, S., Thompson, A. K., Ahmad, F., and Pervez, M. A. (2015). Effect of fruit size and temperature on the shelf life and quality of ripe banana fruit. *Int. J. Agric. Biol.*, 4, 125-133.

[15] Akhter, H., Hassan, M. K., Rabbani, M. G., and Mahmud, A. A. (2013). Effects of variety and postharvest treatments on shelf life and quality of banana. *J. Environ. Sci. Natu. Reso*., 6, 163-175.

[16] Thompson, A. K., Hafiz, I. A., and Asi, A. S. (2001). Post harvest treatment for improving shelf life and eating quality of banana. *Int. J. Agric. Biol.*, 3, 233-235.

[17] Chillet, M., Luc, D. L. D. B., Olivier, H., and Didier, M. (2008). Measurement of ethylene production during banana ripening. *Fruits*, 63, 253-254.

[18] Weiyan Qi, Haijing Wang, Zhen Zhou, Peng Yang, Wenbin Wu, Zhemin Li, Xian Li. (2020). Ethylene emission as a potential indicator of fuji apple flavor quality evaluation under low temperature. *Hort. Plnt. J.*, 6, 231-239.

[19] Statistix. (2006). Statistix 8 user guide, version 1.0. Analytical software, P.O. Box 12185, Tallahassee fl 32317 USA. Copyright © 2006 by Analytical Software.

[20] Scott, K. J., McGlasson, W. B., and Roberts, E. A. (2002). Potassium Permanganate as an Ethylene Absorbent in Polyethylene Bags to Delay Ripening of Bananas during Storage. *Australian J. Exper. Agri*., 10, 237-240.

[21] Ahmad, S., Thompson, A. K., Hafiz, I. A., and Asi, A. S. (2001). Effect of Temperature on the Ripening Behavior and Quality of Banana Fruit. *Int. J. Agric. Biol.*, 1, 22-31.

[22] Chauhan, O. P., Raju, P. S., Dasgupta, D. K., and Bawa, A. S. (2006). Modified atmosphere packaging of banana (cv. Pachbale) with ethylene, carbondioxide and moisture scrubbers and effects on its ripening behavior. *Am. J. Fd. Tech.*, 2,179-189.

[23] Silva, D. F. P., Salomao, L. C. C., Siqueira, D. L., Cecon, P. R., and Rocha, A. (2009). Potassium permanganate effects in postharvest conservation of the papaya cultivar Sunrise Golden. *Pesq. Agropec. Bras., Brasi.*, 44, 669-675.

[24] Santosa, E., Winarso, D., Widodo, and Kholidi. (2010). The use of clay as potassium permanganate carrier to delay the ripening of Raja Bulu banana. *J. Hort. Indo*., 2, 89-96.

[25] Zewter, A., Woldetsadik, K., and Workneh, T. S. (2012). Effect of 1-methylcyclopropene, potassium permanganate and packaging on quality of banana. *Afr. J. Agri. Res*., 16, 2425-2437.