Effect of Potassium Permanganate and Zeolite on Shelf Life and Quality of Musa Acuminata

Chong Yi Yin 1, Maisara Azad Mat Akhir 2, M. N. A. Uda 3 and Nuradibah, M. A. 4
1,2,3,4 School of Bioprocess Engineering, Universiti Malaysia Perlis, Perlis, Malaysia.
E-mail: maisaraazzad@unimap.edu.my

Abstract. This paper study the effect of ethylene scavenger treatments in different quantity (T0: 0 g, T1: 1 g, T2: 3 g, T3: 5 g and T4: 10 g per sachet) and types of packaging (T5: non-perforated and T6: perforated packaging) on Musa Acuminata to its shelf life and physicochemical quality. Potassium permanganate (KMnO4) and zeolite were used as ethylene absorbent which stored together with the bananas under uniform atmospheric condition at temperature of 25-28°C and 85-95% of relative humidity (RH). Physicochemical analysis (e.g. weight loss, peel colour changes, firmness, total soluble solid content and titratable acidity) were performed to evaluate the effectiveness of each treatments throughout its storage period. Results showed that treatment with higher quantity of KMnO4-zeolite (T4: 10 g) shows reduction and retardation in percent weight loss (9.62%), peel colour changes, firmness changes (28.2%), total soluble solid (TSS) (12.1% Brix), titratable acidity (TA) (0.084% malic acid) and also greater storability of banana. Therefore, postharvest losses can be reduced by the mentioned treatment and it can be implemented in postharvest industries for extending the shelf life of banana effectively.

1. Introduction

Musa acuminata is one of the earliest wild species of banana which is distributed mainly on margins of tropical rainforests and is highly diverse in morphological characteristic due to the occurrence of inter-breeding among taxanomy of M.acuminata, particularly in Malaysia [1]. Apparently, there are several threats toward the banana exportation such as unpredictable ripening stage due to prolonged period transport. Ripening is an irreversible process and the time for ripening or senescence process of banana is deviant upon genotypes and species. Banana is one of the highly demanded fruit among populations due to its nutritional benefits, yet it is highly perishable and possess poor shelf life properties due to its rapid ripening process caused by ethylene [2].

Concerning this, ethylene can be scavenged from closed environment storage through adsorption, absorption and oxidation mechanisms by using highly porous materials with high surface area combined with oxidizing agents. For this study, potassium permanganate was used as the ethylene scavenger due to its commonality and is best known as low cost technology used in active packaging [3].

Potassium permanganate (KMnO4) is a powerful oxidant that act as neutralisation agent to ethylene into carbon dioxide and water [4,5]. Several studies confirmed fruit softening is delayed and shelf life extended after the application of KMnO4 [6-8]. However, KMnO4 is not recommended to use directly on fruits due to its toxicity under excessive dosage and purple colour stains [3,9]. For this reason, additional supporting materials are used as the bonding matrix of KMnO4 for safer application. In this project, zeolite is used due to its high porosity and surface area of uptakes which also act as an ethylene absorbent.
2. Material and Methods

2.1. Preparation of coating solutions and sample
Ethylene scavenger (KMnO4 - zeolite) was prepared by 25g of activated zeolite dipped in the saturated solution of KMnO4 (6.4g/100ml) (Sigma-Aldrich) under temperature of 20°C for 90 minutes and dried under air for 30 minutes. The dipping process was repeated for 4 times until the final drying for 24h of the impregnated zeolite achieved. The dried zeolite was grinded into fine powder and filled into tea bags according to specified amount for banana storage treatment [10].

About 6-7 hands of bananas at stage 2 of ripeness indicated by the peel colour (stage 2 of colour index shown in Fig. 1) was bought from the market in Kangar, Perlis. Total of 100 fingers of banana with similar size, weight, peel colour and appearance were selected for storage. The bananas were cleaned and randomly divided into five treatment groups. First screening was carried out with each group consisted of 20 banana fingers stored together with ethylene scavenger (KMnO4-zeolite) in different quantities (T0: 0g as control, T1: 1g, T2: 3g, T3: 5g and T4: 10g). Bananas were stored for a total of 11 days and fruit quality measurement was carried out every 2 days interval to observe the physicochemical changes throughout the treatment.

2.2. Weight loss and firmness evaluation
The physicochemical measurements in terms of cumulative weight gained or losses was measured using analytical balance and was calculated using equation (1). While for fruit firmness were determined using a texture analyser (Brookfield AMETEK CT3-4500-115) equipped with a 4 kg load cell. Firmness evaluation was carried out by penetrating whole unpeeled banana with 2mm diameter probe (TA39) at a speed of 1.0 mm/s with automatic return. The downward distance was set at 10 mm and pre-test speed and post-test speed was 1 mm/s and 10 mm/s; respectively. Banana samples were positioned in the middle of the platform and the measurement were performed in triplicate on each banana at three longitudinal point and the average reading were recorded.

\[ \text{Weight change} = \frac{W_0 - W_1}{W_0} \]

Where:

\( W_0 = \) initial weight before storage;
\( W_1 = \) final weight after storage.

2.3. Total soluble solid and titrable acidity (TA) evaluation
Total soluble solid (TSS) and titratable acidity (TA) contents of banana fruits was measured according to the INIBAP technical guidelines [11]. 30 g of pulp tissue was taken from the traverse section of the sample fruits and grinded with 90 ml distilled water. The mixture was filtered the juice through Whathman filter paper and a drop of the filtrate was placed on the prism of a digital refractometer. The recorded value was expressed in degree brix (ºB).

For titratable acidity, 90 ml of distilled water was added into 30 g of pulp tissue, grinded and filtered. Then 25 ml of the filtrate was transferred into 125ml conical flasks to which 25 ml of distilled water and 5 drops of phenolphthalein indicator was added. Then, it was titrated with 0.1 N sodium hydroxide (NaOH) which is diluted from 250ml distilled water per gram of NaOH. Titration is performed slowly until the indicator changed to pink and the titre volume of NaOH added are recorded. The result was expressed as a percentage per 100 g sample in terms of the predominant acid present, g/L-1 (malic acid) by using equation (2).

\[ \text{Acidity content} = \frac{N \times V_1 \times Eq. wt}{V_2 \times 10} \]
Where, 
\[ N = \text{normality of titrant (0.1N NaOH)} \]
\[ V_1 = \text{volume of titrant} \]
\[ \text{Eq.wt} = \text{equivalent weight of predominant acid (67.05 mg/med malic acid)} \]
\[ V_2 = \text{volume of sample} \]

2.4. Colour changes and shelf-life evaluation
Peel colour of banana can be easily determined by using a standardized colour charts shown in Fig. 1. Banana was scaled from stage 1 (green), 2 (breaker), 3 (<25% colour change), 4 (25-50% colour change), 5 (> 50% colour change but less than 100%), 6 (100% yellow) and 7 (yellow with dark spot and lesions)[12,13].

The shelf life of bananas in different treatment was determined by counting the number of days from peel colour stage 2 (<25% colour changes) to stage 7 (100% colour changes with brown spots) as referred to peel colour index in Fig. 1 [12,14].

Figure 1. Banana pulp colour change chart.

3. Result and Discussion
3.1. Physiological weight loss
Variation of percentage weight loss was observed in different bananas storage treatment. Based on Fig. 2, the percentage of bananas weight loss increases gradually at different rates throughout the 11 days of storage period. This indicates that weight loss occurred over time and was affected by rates of ripening and the maturity stage of bananas. From the analysis presented, untreated bananas (T0) with no KMnO4-zeolite showed significantly highest weight loss of 11.62% on the 11th day of observation. During the ripening process, ethylene action increased respiration rate of bananas and causes the release of moisture through transpiration or evaporation. High rates of transpiration increased the loss of water content that contributed as the physiological weight of bananas as mentioned in the finding of [14-16].

Following that, the trends of bananas weight loss throughout the storage period decreased after the application of ethylene scavenger in different quantity which was grouped as T1 (1g KMnO4-zeolite), T2 (3g), T3 (5g) and T4 (10g). This confirmed that KMnO4-zeolite as ethylene scavenger are able to retard the weight loss of bananas due to the restrain action of ethylene gases. KMnO4 oxidized ethylene and released CO2 and H2O as vapour increased the storage humidity whereby reduces rate of transpiration that causes moisture losses. Concurrently, bananas that stored with 10g KMnO4-zeolite (T4) shows the least weight loss (9.62%) as compared to other treatments. The trends of bananas weight loss among treatments varied due to the different rates of oxidation and adsorption of ethylene gases throughout the storage period.
3.2. Peel colour changes

Peel colour changes on fruits is one of the visual indication of ripening due to the degradation of chlorophyll pigmentation caused by the enzymatic activities [13]. Initially, peel colour of banana fruits were greenish (stage 2) and were subsequently change to yellowish at ripening throughout the storage period as shown in Fig. 3. The fastest colour change of bananas was observed in T0 with no KMnO4-zeolite and it reached stage 7 on the 9th day of storage earlier than other treatment. As KMnO4-zeolite was applied, peel colour changes were retarded and remain greenish in longer period as compared to T0. This was in line with the finding of [5] which stated that peel colour development of silk bananas was delayed with the application of zeolite- KMnO4 tablets.

The results showed slow colour changes occurred with the increasing quantity of dosage indicated by the variation of each treatment. From there, the slowest colour change was observed in T4 with highest dosage quantity (10g KMnO4-zeolite) which maintain the peel colour of bananas at stage 2 up to 7 days before it turned to further stage at the following days (Fig. 3 and 4). As the observation was continually carried out, peel colour of bananas in T4 reached stage 7 on the 15th day. This was in line with previous research which stated that high quantity of ethylene scavenger provides longer period of oxidation of ethylene gases whereby retarding the ethylene action that causes chlorophyll degradation [15,17].

Overall, the finding was associated with the shelf life of bananas which was determined from the period for peel colour changes from stage 2 to stage 7. Therefore, shelf life of bananas in T0 (9 days) is the lowest while in T4 is the highest at 15 days.
5

3.3. Firmness and total soluble solid changes

Referring to Fig. 5, the firmness of bananas at the unripe stage is higher and decrease gradually throughout the ripening process without treatment (T0) with the highest firmness reduction (71.6%) at the end of storage period. The firmness changes of bananas for T1 (69%), T2 (60.6%), T3 (52%) and T4 (34.9%) on the 11th day of storage indicates that higher quantity of KMnO4-zeolite offers slower softening of fruits. Therefore, the highest firmness of bananas was remained in T4 as compared to other treatments. Higher amount of KMnO4 results in higher absorbance of ethylene and reduce its destructive effects on cell walls by reducing polygalacturonase and cellulose activity [15]. Thus, firmness of bananas can be maintained and preserve in the higher application of ethylene scavenger.

3.4. Total soluble solid and titratable acidity changes

As banana starts ripening, the TSS content increases due to the breakdown of starch to simpler sugar. TSS content increased with fruits ripening and respiration rates. The increase of TSS reflects the sweet taste in fruits that helps to enhance its flavour and astringent taste. Based on Fig. 6 (a), the highest increase of TSS was experienced in T0 (control) bananas throughout the storage period. Bananas undergoes normal respiration and ripening process with the aids of ethylene which speed up the
enzymatic activity and chemical reactions within fruits such as breakdown and hydrolysis of starch to sugar. Meanwhile, the lowest increases of banana TSS was observed in T4 with 10g of KMnO4-zeolite. On the last day of observation (day 11), TSS of T0 and T4 bananas were recorded as 19.4% brix and 9% brix respectively. These results implied that KMnO4-zeolite were effective to delay breakdown of starch content because the application of KMnO4-zeolite tablets lowered TSS up to 1 week compared to controlled condition. Thus, maintaining the TSS at lower level by KMnO4 treatment may be due to slow rate of respiration and ripening processes.

The respiration and fruit physiology activities of climacteric fruits like banana were continued after harvesting. TA of bananas first increased during the ripening process where organic acid content (mainly malic acid, oxalic acid and citric acid) from carbohydrates were synthesized. When the fruits were fully ripened, acid content reached the peak and started to degrades. The fruit metabolism started to causes reduction of fruits acidity and change to sugar content. This results characteristic can be observed in T0 (control) where TA of bananas reach the peak at 0.099 % malic acid on the 7th day of observation indicating the bananas have fully ripened (Fig. 6b). Then, TA started to reduced due to the conversion of sugar content. The reduction of acidity increment by KMnO4 being a strong oxidizer is due to the destruction of ethylene chemical reaction. Significance distinction (F> Fcritical and P < 0.05) among treatments shows the effect of KMnO4-zeolite in variable quantities towards the change of TA. Subsequently after T0, T1 (1g KMnO4-zeolite) reached the peak at 0.101% malic acid on the 9th day of observation. However, the rest of the treatments (T2, T3 and T4) have not yet arrive at its peak point during the 11 days of storage (Fig. 6b).

From Fig 6(b), T4 shows the most reduced TA (0.084% malic acid on day 11 of storage) as compared to other treatments due to restricted reaction of ethylene by the relatively higher amount of KMnO4-zeolite. The use of KMnO4 contributes to an increase in the CO2 concentration as ethylene is degraded into CO2 and water [18]. This CO2 accumulated in the fruit tissue and after dissolving formed carbonic acid, causing acidosis. The changes of pulp acidity are mainly caused by the changes in malic acid, citric acid, oxalic acid and potassium during postharvest ripening of banana fruits [19]. Nevertheless, increase in the permanganate level inside the packing reduced the TA whereby indicating retarded ripening of fruits [20].
4. Conclusion

As a conclusion, the application of ethylene scavenger (KMnO$_4$-zeolite) retards the ripening and physico-chemical changes of bananas. This investigation indicated that KMnO$_4$-zeolite is a potent ethylene action inhibitor that inhibit ripening and maintaining the quality of banana fruits related to expanded marketability. These changes resulted in slowing down the ripening and senescence, enhancing shelf life and maintaining fruit quality during storage. Moreover, it is demonstrated that higher quantity of ethylene scavenger provides longer effects towards the oxidation of ethylene gases. Therefore, bananas in T$_4$ (10g KMnO$_4$-zeolite) shows the slowest increase of weight loss (9.62%), firmness changes (34.9%), colour changes, TSS (9% Brix) and TA (0.084% malic acid) on the last day of observation. Lastly, bananas in T$_4$ have the longest shelf life of 15 days as compared to other treatments.

References

[1] X. Perrier et al. 2011 *Proceedings of the National Academy of Sciences of the United States of America*. 108, 11311–11318.
[2] H. Akter, M. Hassan, M. Rabbani and A. Mahmud 2015 *J. Environ. Sci. Nat. Resour*. 6 2.
[3] K. K. Gaikwad and Y. S. Lee. 2017 *Korean J. Packag. Sci. Technol*. 23, 2, 109–117.
[4] D. F. P. Silva, L. C. C. Salomão, D. L. de Siqueira, P. R. Cecon, and A. Rocha. 2009 *Pesqui. Agropecuária Bras*. 44 7 669–675.

Figure 6. Effects of ethylene scavenger (KMnO$_4$-zeolite) with different quantities on (a) total soluble solid content, (b) acidity content of *M.acuminata* during 11 days of storage.
[5] S. Yimmongkol, P. Pratumpong, S. Boonyuen, and C. Pechyen. Chiang Mai 2018 J. Sci. 45(5) 2152–2167.
[6] F. Khosravi, M. Khosravi and E. Pourseyedi. 2015 Int. J. Life Sci. 9(2) 55–60.
[7] S. B. Murmu and H. N. Mishra 2018 Food Chem. 253 55–62.
[8] P. C. Spricigo, M. M. Foschini, C. Ribeiro, D. S. Corrêa and M. D. Ferreira 2017 Food Bioprocess Technol. 10 9 1622–1630.
[9] S. E. Cevik, O. Yesil, T. C. Ozturk and O. Guneysel 2012 Clin. Pract. 2(2) 32.
[10] R. Dobrucka, A. Leonowicz and R. Cierpiszewski 2017 Stud. Oeconomica Posnaniensia. 5(7) 7–18.
[11] Dadzie, B. K. and Orchard, J. E. 1997 Routine post-harvest screening of banana/plantain hybrids: criteria and methods (Vol. 2). Bioversity International.
[12] A. S. N. Aditya Madan and R. K. Jain Journal of Food Science & Technology. 3 1.
[13] S. Sau et al. 2017 The Bioscan. 12(1) 95–100.
[14] T. Ashwini, S. Ganapathy, K. S. Subramanian, C. Indu Rani and G. Guru Meenakshi 2018 Int. J. Curr. Microbiol. Appl. Sci. 7(2) 2441–2450.
[15] E. Santosa, W. D. Widodo and , Kholid 2013 J. Hortik. Indones. 1(2) 88.
[16] T. Krishnakumar and T. Venkatachalam 2014 Trends in Biosciences. 7(22) 3673-3679.
[17] P. C. Spricigo, M. M. Foschini, C. Ribeiro, D. S. Corrêa and M. D. Ferreira 2017 Food Bioprocess Technol. 10(9) 1622–1630.
[18] A. Frigola 2016 MOJ Food Process. Technol. 3 2.
[19] A. Etienne, M. Génard, D. Bancel, S. Benoit and C. Bugaud 2013 Sci. Hortic. (Amsterdam). 162, 125–134.
[20] B. M. A. . Chaves, M. A.; Bonomo, R. C. F.; Silva, A. A. L.; Santos, L.S.; Carvalho and R. D. Souza, T. S.; Gomes, G. M.S; Soares 2007 Cienc. Tecnol. Aliment. 5(5) 346-351.