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THE EFFECTS OF THE USE OF CORRUGATED CARDBOARDS COVERED WITH ETHYLENE ABSORBERS ON MANGO FRUIT QUALITY AFTER SHORT-TERM STORAGE (*MANGIFERA INDICA* L.)

Short communication

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ABSTRACT

Corrugated cardboard covered with ethylene absorbers is an innovation that can be used to extend the shelf life of mango fruit to slow the loss of fruit quality. Mango fruits 'Gedong' were placed in boxes having as the inner parts corrugated cardboard covered with ethylene absorbers. Three storage treatments – corrugated cardboard without ethylene absorber, with activated carbon or activated carbon + potassium permanganate – were used to find the best method to prevent quality deterioration of mango. The color change, mass loss, texture value, and total soluble solids content were evaluated after 10 days of storage. The initial results showed that the highest accumulation of ethylene production by fruit samples was 0.628 $ppm \cdot kg^{-1}$ on the fourth day after harvest, while the total ethylene production during 8 days of storage was 2.231 $ppm \cdot kg^{-1}$. The use of ethylene absorbers had significant effects on the quality parameters except for the color changes. Storage for 10 days in boxes lined with corrugated cardboard ethylene absorber in form of activated carbon + potassium permanganate resulted in the lowest mass loss (4.40 ± 2.6%), softness (0.2 ± 0.1 $mm \cdot g^{-1} \cdot s^{-1}$) and total soluble solids (14.7 ± 1.2 °Brix).

Keywords: corrugated cardboard, ethylene absorber, quality deterioration

INTRODUCTION

Mango (*Mangifera indica* L.) is a climacteric fruit that shows an increasing respiration and ethylene production (Nurjanah 2002). Indonesia is the fourth largest producer of mangos (mango, mangosteen, and guava) with the average production in 2016 reaching 2,345,753 tons (FAOSTAT 2018). Total production of mango in Indonesia was 1,814,550 tons in 2016, with the total export of 473,266 tons (Statistic Indonesia 2017). To fulfill the requirements of the export market, the high production and high quality of mango fruit is needed. Some cases of rejection of export products occurred because of quality deterioration, including discoloration, mass loss and low firmness, which is caused by metabolic processes, such as respiration and ethylene production.

The characteristics of fruit and vegetables can be described by color, flavor (taste and aroma), texture and nutritional value (Barrett et al. 2010). Color was the major property to determine the maturity level of fruit that generally indicates the quality of flavor, edibility, shelf life and nutrition value (Lawless & Heymann 2010). Color change is caused by degradation of chlorophyll in the maturation process. The texture of mango can be described by firmness, which is one of the parameter that indicates the maturity level (Zerbini et al. 2015; Rahman 2007)

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and need to be taken into consideration during storage and sale. The decreasing value of firmness (softness)accelerates the quality deterioration and increased the risk of fruit damage through handling treatments. Fruit softness occurs due to major changes in the cell walls structure during the ripening process.

Another important parameter is the mass lost, which results from the carbon loss during metabolic activity that provides energy from carbohydrates producing carbon dioxide, water, and heat energy (Fonseca et al. 2002; Finnegan & O'Beirne 2015). The major part of the mass loss results from water loss. It causes wilting and shriveling and has an immediate economic effect in reducing saleable weight (Brackmann et al. 2014). To prevent quality deterioration of mango fruit, optimization of postharvest handling is needed during storage and distribution. One of the technologies that can be applied is the ethylene absorption.

Potassium permanganate is an ethylene oxidizing agent that can be used to convert ethylene into mangandioxyde, potassium hydroxide, and carbon dioxide (Ahvenainen 2003). It would be more effective in liquid form but its application in this form is troublesome (Syamsu et al. 2016). Based on this condition, the inert material, as zeolite (Syamsu et al. 2016, Widayanti et al. 2016), alumina beads (Wills & Warton 2004), vermiculite (Blanke 2014) or activated carbon (Araújo et al. 2015) can be used to absorb $KMnO_4$ from a liquid form.

In this study, activated carbon based on coconut shells was used as the inert material to absorb potassium permanganate. Ethylene absorber is widely used for direct application as the material ingredient in the packaging system. Sachet forms are commonly used because of their easy handling; they only need to be placed freely in the headspace of the packaging system. However, the use of sachets gives a higher possibility of material leakage compared to the other forms. This causes a fear of the contamination of stored products and materials by ethylene absorbent. This problem can be prevented by minimizing the direct contact between products and the absorber materials. The application of ethylene absorber materials on corrugated cardboard allowed minimal contact between fruits and absorber materials. It happens because the absorber materials are glued to the surface of corrugated ply and then glued together with a liner to make a corrugated cardboard form.

The objective of this research was to determine the effectiveness of corrugated cardboard covered with ethylene absorber on the quality of mango fruit 'Gedong' after a 10-days storage.

MATERIAL AND METHODS

The corrugated cardboard covered with ethylene absorbing agents was obtained from previous studies (Aprilliani et al. 2019). It was shaped into 26 × 21 cm rectangles. The absorbent – activated carbon (AC) – was glued (cassava starch and gelatin) on the surface of corrugated ply. The surface was than impregnated with potassium permanganate (AC-$KMnO_4$), purchased from CV Mulia Jaya, Bogor, West Java, Indonesia.

To study the ethylene absorption capacity, 1 ml of gas containing 100 ppm ethylene was injected into gas-tight jars, to which 5 sheets of corrugated cardboard AC or AC-$KMnO_4$ was placed. The ethylene concentration was measured after 15–75 min using gas chromatography (GC model 263-50, Hitachi, Japan) equipped with flame ionization detection (FID), by operating conditions of a column temperature at 85 °C, injector and detector temperature at 150 °C and 200 °C, respectively. The velocity of helium gas flow was 30 ml min^{-1} and the pressure maintained at 100 psi. The scanning electron microscope (SEM) was used to study the surface of activated carbon before and after the impregnated process. The samples were placed onto adhesive carbon tape supported with metallic disk (Boparai et al. 2011) and then the microscope captured the images of the surface area of the samples by scanning it with a high energy beam of electrons (Javed et al. 2008). The surfaces were observed on randomly selected areas at × 5000.

Fresh harvested mango fruit 'Gedong' at 80–85% maturity level was purchased from exporter CV. Buah SAE in Cirebon, West Java, Indonesia. The ethylene production of mango fruit after harvest was measured in the gas-tight jars (8 days at 18 °C) by using gas chromatograph, as above, for control treatment. Freshly harvested mango fruits, free of defects were sorted for the same size and weight of approximately 530–550 g. Fruits were dipped into 50 ± 1 °C water (HWT) for 10 min (Yimyong et al. 2011), then after drying at room temperature were placed in jars. The jars was closed for 24 h then opened for 10 min every day for 8 days. As much as 1 ml of gas headspace was injected into GC to calculate the ethylene production rate from the fruit samples closed in the jar.

To find out the effect of ethylene absorption on the quality of mango fruits during storage, fruit samples with weighing approximately 300–350 g were placed at room temperature and allowed to dry before the precooled process for 24 h at 18 °C (70% of relative humidity) until used. The fruits were divided into three parts for storage under following conditions: without ethylene absorbers (A0), with AC corrugated cardboard (A1) and with corrugated cardboard with AC+$KMnO_4$ (A2). The samples were stored at 18 °C and 70% RH for 10 days. The evaluation was carried out with three replications per each treatment using at least 54 fruits in the experiment for 6 days of observation.

The quality deterioration of mango fruit was determined by analyzing the color properties, mass loss, texture, and total soluble solids (TSS). The color properties of sample mango were determined using Chroma Meter Minolta for CIE L*a*b* scale. The values of L*a*b* were obtained from three points (top, middle, and bottom) of each mango fruit and then the a* and b* values were converted into Hue angle (°H) and Chroma (C*). The texture was analyzed using Penetrometer Precision Scientific Petroleum Instruments with a needle (a = 2.8 g). The lever/clutch of penetrometer was pressed for 5 s (t). The value from the measurements shows the penetration depth (mm). The texture analysis was expressed by dividing the result of penetration depth with the needle weight and time reading with the unit of measurement was $mm \cdot g^{-1} \cdot s^{-1}$, according to Sumarmono (2012). The smaller value of texture indicated that the fruit was more firm compared to the sample with a higher value. The mass loss of sample was measured from three replications for each treatment and then expressed as percent (%) mass loss. Total soluble solids (TSS) were measured in the juice of each sample and analyzed by using a refractometer and expressed as °Brix.

All data were statistically analyzed using ANOVA followed by a comparison of means using Duncan's multiple range test at $p < 0.05$.

RESULTS AND DISCUSSION

Comparison of corrugated cardboard surfaces covered with activated carbon before and after impregnation with $KMnO_4$

A surface view of cardboard AC-covered (Fig. 1A) shows clean pore surface area ready to be used for the impregnating process. The surface of cardboard AC+$KMnO_4$-covered (Fig. 1B) shows a layer of potassium permanganate. The presence of $KMnO_4$ on the pores and surface area covered with activated carbon will facilitate an optimum capacity of the ethylene oxidation process.

Ethylene production by mango fruit 'Gedong'

The ethylene production of mango was analyzed using GC. Generally, the ethylene production of mango fruit increased during storage and reached the peak on the third day of measurement or 4 days after harvest (DAH). Our results fit with the statement of Nurjanah (2002), who revealed that the ripening process is accompanied with an increasing level of CO_2 and ethylene until it reaches maximum and then the values decrease after the ripening period. The maximum ethylene production rate reached 0.6282 $ppm \cdot kg^{-1}$ on the 4^{th} DAH, and total ethylene production within 8 days of storage was 2.2262 $ppm \cdot kg^{-1}$ (Fig. 2).

Ethylene is a factor that naturally accompanies the ripening and shelf life of fruit and as such must be taken into account in fruit packaging and storing process. Ethylene is a hormone that is effective at concentrations raging from parts per million (ppm) to parts per billion (ppb). Ripening is a process, in which the structures of the organ are developmentally altered, including, changes in texture, flavor, and aroma (Giovannoni 2004). Once the ripening process has started, the concentration of ethylene gases quickly increases (Saltveit 1999).

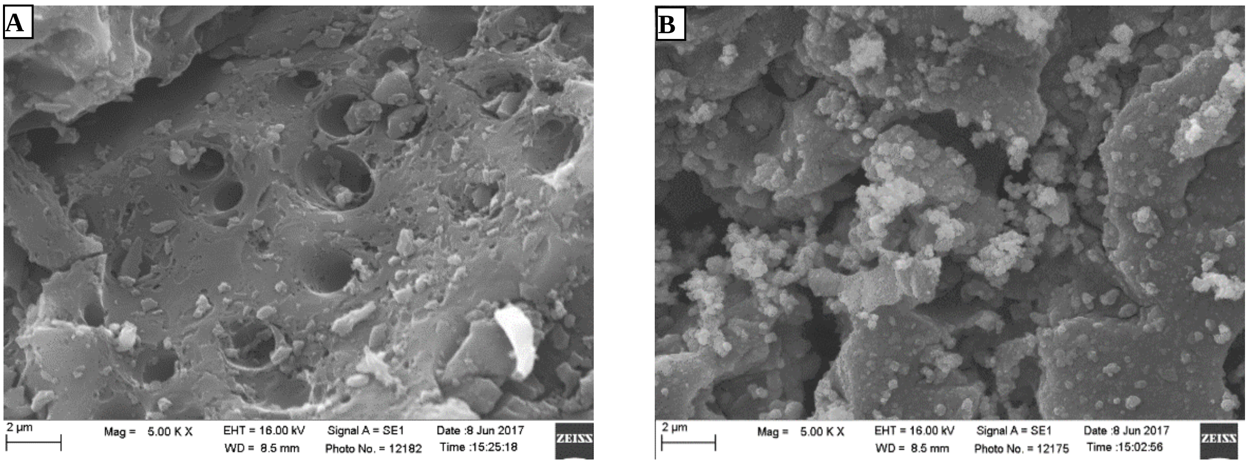

Fig. 1. Scanning electron microscopy images: (A) activated carbon; (B) activated carbon impregnated with $KMnO_4$ at × 5000

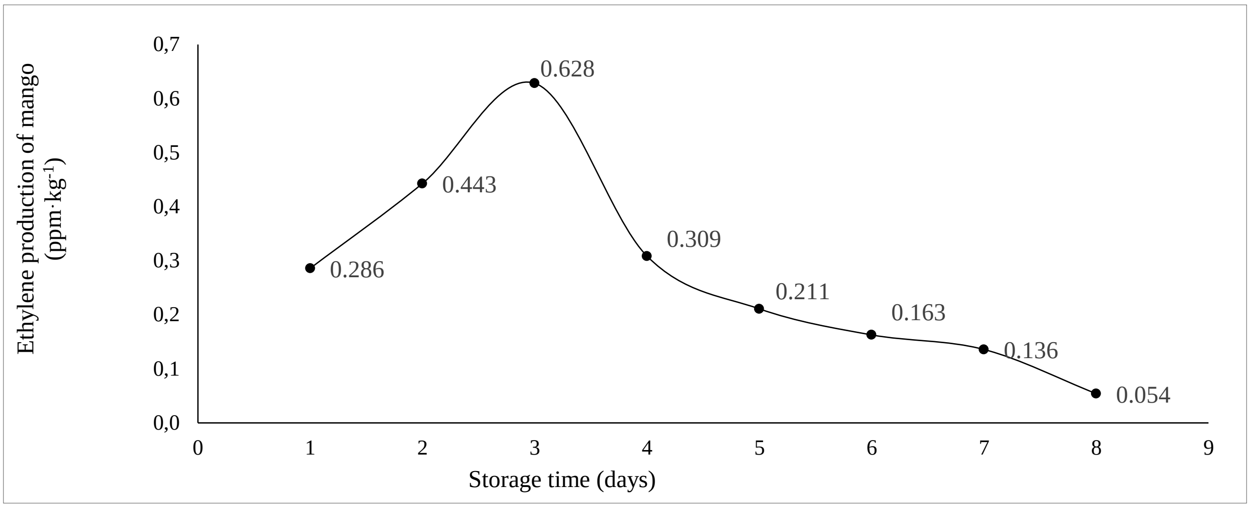

Fig. 2. The ethylene production rate of mango fruit 'Gedong' during storage

Table 1. The effect of storage treatments on the quality of mango fruit 'Gedong' after 10 days

Storage conditions	Color properties			Mass loss (%)	Texture analysis ($mm \cdot g^{-1} \cdot s^{-1}$)	TSS (°Brix)
	lightness (L*)	chrome (C*)	hue (°H)			
Control	57.95±2.32	45.04±4.28	72.98±13.02	5.57 ± 3.17^c	0.4 ± 0.2^c	16.0 ± 2.2^c
AC	57.35±2.52	43.44±9.25	73.14±14.21	5.21 ± 2.87^b	0.3 ± 0.1^b	15.3 ± 1.6^b
AC-$KMnO_4$	57.92±0.84	43.75±5.32	72.72±13.93	4.40 ± 2.6^a	0.2 ± 0.1^a	14.7 ± 1.2^a

All values are mean ± SD. Different superscript letters in same column are significantly different by a comparison of means using Duncan's Multiple Range Test at $p < 0.05$.

The amount of corrugated cardboard ethylene absorber was obtained from the calculations of the ethylene production of mango fruit and the optimal ethylene absorption capacity of corrugated cardboard covered with AC-$KMnO_4$, based on our earlier findings (Aprilliani et al. 2018). The corrugated cardboard ethylene absorber AC-$KMnO_4$ showed the highest ethylene oxidation capacity of 0.0745 $ppm \cdot g^{-1}$, whereas the ethylene oxidation capacity of corrugated cardboard AC was 0.0008 $ppm \cdot g^{-1}$. From the calculations, 29.95 g of ethylene absorber materials (equal to 6 sheets of size 26 × 21 cm of corrugated cardboard AC-$KMnO_4$) is needed for each kilogram of mango fruit 'Gedong' for 8 days of storage.

The effect of storage conditions on the quality of mango fruit

The applied storage treatments influenced significantly all the traits of the quality deterioration of mango 'Gedong' at $p < 0.05$, except for the color changes (Table 1). The storage with corrugated cardboard covered with AC-$KMnO_4$ showed slow quality deterioration. This means that the use of corrugated cardboard AC-$KMnO_4$ in the appropriate concentration can prevent the quality deterioration and delay the ripening process of the mango. The parameters of fruit color in control with no ethylene absorption were not significantly changed either (Table 1). However, the use of ethylene absorbing materials AC and AC-$KMnO_4$ retarded color degradations to some extent. The lowering concentration of ethylene in the packaging boxes resulting from using ethylene absorbers lowered metabolism stimulating activity of ATPase that delays the ripening process and the degradation of chlorophyll.

The mass loss and softness increased during storage (Table 1). The storage without ethylene absorber materials showed the highest mass loss – 5.57 ± 3.17% and softness value of 0.4 ± 0.2 $mm \cdot g^{-1} \cdot s^{-1}$ after 10 days of storage, while the presence of corrugated cardboard covered with AC-$KMnO_4$ decreased mass loss to 4.40 ± 2.6% and fruit softening to 0.2 ± 0.1 $mm \cdot g^{-1} \cdot s^{-1}$. The above changes were the result of ethylene absorbed by AC-$KMnO_4$ thus it is causing a decrease in acceleration of the activity of ATPase and in consequence delaying ripening process of mango fruit during storage.

Total soluble solids (TSS) increased during storage due to the degradation of carbohydrates into sucrose, glucose, and fructose (Holcroft 2015). The highest value of Brix was obtained in control sample without ethylene absorber materials (Table 1), which was caused by the high accumulation of ethylene in the headspace of storage box, resulting in acceleration of degradation of carbohydrates. The TSS analysis after 10 days of storage in corrugated cardboard covered with AC-$KMnO_4$ was 14.7 ± 1.2 °Brix and 16.0 ± 2.2 °Brix for the control fruit.

The quality of mango decreased during storage, which was characterized by the increased mass loss, fruit softness, total soluble solids (TSS) and also color changes. Using corrugated cardboard covered with AC-$KMnO_4$ ethylene absorber can prevent the quality deterioration and also extend the shelf life of mango fruit 'Gedong' during storage.

In conclusion, we advise the use of corrugated cardboards covered with ethylene absorber in the form of AC+$KMnO_4$ for preventing deterioration of mango fruit during storage and marketing.

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