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(RESEARCH ARTICLE)

The effect of potassium permanganate concentration and storage time after harvesting fruit on physiological ripeness on the quality of sapodilla (*Manilkara zapota* L. cv. Dawan) during storage

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Abstract

Climacteric fruit is a type of fruit that will continue to undergo a respiration process after the fruit is harvested, ethylene gas increases so that the fruit ripens more quickly than non-climacteric fruit. Sapodilla is a climacteric fruit, so a proper postharvest handling technique is needed to prolong ripening and damage to the fruit relatively quickly. The purpose of this study was to determine the concentration of potassium permanganate and the best degree of fruit ripeness to maintain the quality of the sapodilla cv. Dawan fruit during storage. This research used a completely randomized design with two factors and three replications. The first factor is the concentration of potassium permanganate with four levels, i.e., control level (P0), concentration of 75 mg/100 ml of water (P1), concentration of 90 mg/100 ml of water (P2), and concentration of 105 mg/100 ml of water (P3). The second factor was the level of maturity with three levels, i.e., physiological immature fruit (Tk), fruit with physiological ripeness level (Tm), and fruit with a degree of maturity after physiological maturity (Ts). The results showed that the concentration of potassium permanganate and the level of maturity and the interaction had a significant effect on the quality of sapodilla during storage. On the first factor, the concentration of potassium permanganate 105 mg/100 ml of water gave the best sapodilla quality with the lowest decrease in fruit weight, the lowest increase in weight loss, and the lowest decrease in fruit water content. On the second factor, the level of physiological immature fruit gives the best quality of sapodilla with the lowest decrease in fruit weight, the lowest increase in weight loss, and the lowest decrease in fruit water content.

Keywords: Climacteric Fruit; Maturity; Potassium Permanganate; Sapodilla

1 Introduction

Climacteric fruit is a type of fruit whose respiration rate will continue to increase after the fruit is harvested. In general, climacteric fruit will quickly experience damage due to respiration, physiological, and transpiration processes that continue even though the fruit has been harvested [1]. Increased respiration rate and high production of ethylene gas in climacteric fruit cause a rapid ripening process after harvest. Sapodilla fruit is an example of a horticultural product that is classified as a climacteric fruit so it will experience rapid damage if proper handling is not carried out immediately. The chances of success for sapodilla in Indonesia are also great because of the high economic potential because the skin and other parts can be utilized, but the flesh part is a commodity that is easily damaged and rots, so proper post-harvest handling is needed. When the sapodilla fruit is physiologically ripe, the shelf life of the fruit only lasts 3-5 days and after that, it is too ripe [2]. If the pass is stored for more than the limit of that day, signs of damage to the sapodilla fruit will be seen such as rot [2]. Therefore, proper fruit handling methods/techniques are needed to maintain the quality of sapodilla fruit during storage. Potassium permanganate ($KMnO_4$) can be used as a delay in ripening and rapid decay by inhibiting the occurrence of respiration spikes and increasing ethylene production during fruit storage so that the quality of sapodilla fruit is maintained during storage. $KMnO_4$ applications4 can significantly extend the shelf life of Barangan bananas up to 10 days [3]. The use of $KMnO_4$ combined with wood saw shavings as an absorbent material has

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been able to inhibit the amount of oxygen entering the fruit so that it can reduce the rate of respiration and inhibit the breakdown of glucose [4].

2 Material and methods

2.1 Material and tools

The material used in this study was sapodilla (*Manilkara zapota* L. cv. Dawan) according to the maturity level taken from the sapodilla fruit production center in Dawan Klod Village, Dawan District, Klungkung regency, Bali. As ethylene oxidizer used $KMnO_4$ with different concentrations, sawdust with the same concentration as a conducting medium, pure water as a solvent, gauze, and cardboard box. The tools used include scales, measuring cups, hand refractometers, fruit graters, cutting knives, ovens, and chemical analysis tools.

2.2 Methods

This research used a completely randomized design with two factors and three replications. The first factor is the concentration of potassium permanganate with four levels, i.e., control level (P0), a concentration of 75 mg/100 ml of water (P1), a concentration of 90 mg/100 ml of water (P2), and a concentration of 105 mg/100 ml of water (P3) while the second factor is the level of maturity with three levels, i.e., physiological immature fruit (Tk), fruit with physiological ripeness level (Tm), and fruit with a degree of maturity after physiological maturity (Ts).

2.3 Harvest fruit according to the maturity level and cleaning of fruit samples

Fruit samples that have been obtained, are then cleaned of dirt until clean, drained until dry, and sorted based on the level of ripeness, and placed in each cardboard box.

2.4 Storage of fruit according to the level of treatment

Storage of Sapodilla cv. Dawan samples was carried out for 9 days, by making observations on days 0, 3, 6, and 9 days after storage (DAS). Fruit samples are stored according to the level of treatment and consist of fixed samples and destructive samples. The sample is still used to observe weight loss and changes in fruit color. While the destructive samples were used to observe total dissolved solids, fruit moisture content, and vitamin C content.

2.5 Variable observation

Weight loss

Loss of weight (%), is measured by calculating the difference between the initial sample weight and the final sample weight compared to the initial sample weight which is carried out every three days of observation.

Water content

The water content of fruit (%) was obtained by cutting the fruit and weighing its fresh weight. Then, oven at 105 0C and weighed until constant. After that, the cup and dry sample were weighed. In the last step, calculations can be carried out to find out the percent water content in the fruit. These observations were made every three days during storage.

Fruit hardness

The fruit hardness (kg/cm2) was measured with a penetrometer by setting the pointer on the depth scale to zero. Then do the peeling of the fruit skin in the part that will be stabbed. The fruit is in the left hand, the penetrometer is in the right. Pierce the fruit, and read how far the marker scale has shifted from zero. Take measurements at several places (tip, middle, and base of the fruit) to get the average hardness value of the fruit every three days of observation.

Vitamin C content

The content of vitamin C, is measured by the method of iodine titration. Observations were made on the last day of observation. Fruit that has been crushed, weighed 10 g. Then dissolved into 50 ml by adding distilled water, and filtered using filter paper. After obtaining sapodilla extract, take 10 ml and drip with 1 ml of starch solution, then titrate with 0.1 N iodine until the blue color does not disappear within 30 seconds.

2.6 Data analysis

Observational data were analyzed using analysis of variance at the significant effect level of 5% and 1%. If there is a real influence on the interaction, then proceed with Duncan's test. If a single factor has a significant effect, then proceed with the LSD test at the 5% level

3 Results and discussion

3.1 Weight loss

The highest fruit weight loss at nine days of storage was in P_0 (24.16%) meanwhile the lowest increase in weight loss was found at the concentration P_3 (19.58%) although not significantly different compared to other treatments at three to nine days after storage (DAS) (Table 1). The weight loss tends to increase at all three levels of storage time after the fruit is harvested at physiological mature maturity. T_k with the lowest reduction in fruit weight also gave the lowest fruit weight loss of 17.68% compared to T_m and T_s 23.10% and 23.20%. This is also in accordance with the results of research by Budiman [5], which stated that the highest concentration of ethylene oxidizing agent 90 grams, was able to inhibit the increase in weight loss until the end of the observation compared to the concentration of ethylene oxidizing agent 60 grams and 75 grams which had higher weight loss values. The occurrence of fruit weight loss is influenced by the separation of cells along the middle lamella whose porosity will decrease as the fruit ripens [5]. The appropriate $KMnO_4$ concentration gave an effect on weight loss because it can inhibit the increase in weight loss in fruits that experience high respiration rates such as sapodilla fruit. The weight loss is closely related to water content, where the higher the water loss in the fruit, the fruit weight loss will be higher [8]. This is also according to research by Kusmiyati et al. [6] found that sapodilla fruit stored 5 days experienced the highest decrease in water content than physiological mature maturity stored for 0 days. The sapodilla fruit harvested at the level of physiological mature maturity were stored for 0 days has the lowest weight loss compared to fruit harvested at the level of physiological stored 2 and 4 days because at that time sapodilla fruit is generally suitable for harvesting and is at the early stage of maturity.

Table 1 Single Factor Results Using Concentration of Potassium Permanganate (P) and Maturity Level (T) to Weight Loss Variable (%)

Treatment	**Weight loss on storage time (das)**		
	3	**6**	**9**
Concentration of $KMnO_4$	.....%.....		
P_0	6.36 a	15.21 a	24.16 a
P_1	1.95 a	11.22 a	20.10 a
P_2	1.24 a	12.03 a	21.47 a
P_3	1.47 a	10.75 a	19.58 a
BNT 5%	4.924	4.854	5.026
Maturity Level	.....%.....		
T_k	3.63 a	11.42 a	17.68 b
T_m	3.55 a	13.47 a	23.10 a
T_s	1.09 a	12.42 a	23.20 a
BNT 5%	4.264	4.204	4.352

Description: Numbers followed by the same letter in the same treatment and column show no significant difference in the 5% level of low significant difference test (LSD); ns: not significantly

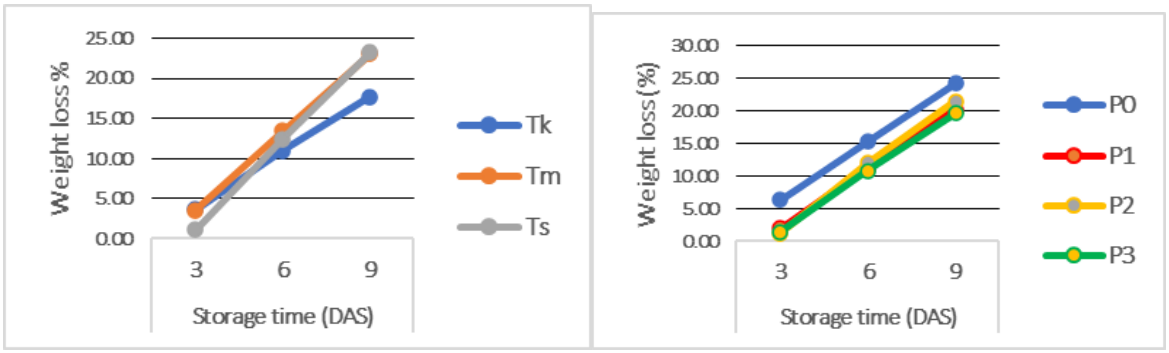

Figure 1 Effect of storage concentration of **$KMnO_4$** and level of maturity on fruit weight loss

3.2 Water content

The water content of the fruit at 3 to 9 days of storage showed no significant difference in P_0, P_1, P_2, and P_3. However, at 6 days after storage (DAS) P_3 showed a significant difference in P_0, P_1, P_2, and P_3. The highest decrease in water content occurred at P_2 (3.8%) and the lowest at P_3 (1.5%). This is in accordance with the results of a study by Budiman [5], with showed that the presence of an appropriate ethylene oxidizer was able to minimize or inhibit high water loss during the respiration process so that the main cause of deterioration due to wilting and shrinking of the fruit skin was getting smaller. Arini et al. [7] found that untreated papaya experienced significant water loss due to faster respiration and transpiration processes. It was also stated that the use of $KMnO_4$ with the appropriate concentration can bind ethylene to manganese dioxide (MnO_2) [7]. The water content of the fruit also tends to decrease for each length of storage after the fruit is harvested at physiological mature maturity. Where the percentage of decrease in fruit water content was highest at T_m (4.0%), lowest at T_k (1.6%) while T_s (2.2%) (Table 2) and (Figure 2). Water content is closely related to fruit weight loss, where the higher the water loss in the fruit, the fruit weight loss will be higher [8].

Table 2 Single Factor Results Using Concentration of Potassium Permanganate (P) and Maturity Level (T) of Variable Water Content of Fruit (%)

Treatment	**Water content during storage (das)**		
	3	**6**	**9**
Concentration of $KMnO_4$	.....%.....		
P_0	75.64 a	76.51 a	74.04 a
P_1	76.33 a	75.07 a	73.93 a
P_2	76.09 a	75.49 a	73.20 a
P_3	76.09 a	72.98 b	74.98 a
BNT 5%	2.476	2.271	1.917
Maturity Level	.....%.....		
T_k	75.28 b	74.93 a	74.05 a
T_m	77.62 a	75.45 a	74.48 a
T_s	75.22 c	74.65 a	73.38 a
BNT 5%	2.144	1.967	1.659

Description: Numbers followed by the same letter in the same treatment and column show no significant difference in the 5% level of low significant difference test (LSD); ns: not significantly different

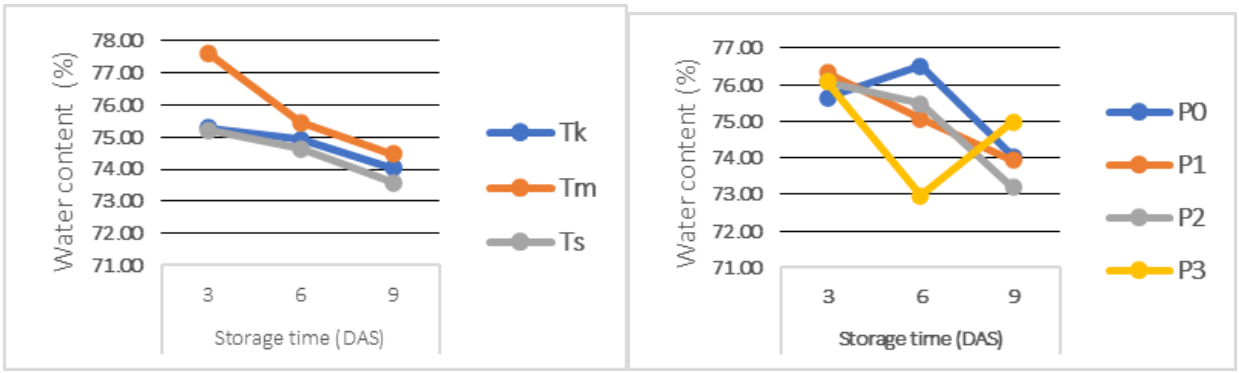

Figure 2 Effect of storage concentration of **$KMnO_4$** and level of maturity on fruit water content

3.3 Fruit hardness

The highest fruit hardness was obtained in the combination of $KMnO_4$ concentrations 105 mg/100 ml of water and the use of physiologically immature fruit (P_3T_k) from 3 to 6 days of storage (DAS) with the hardness on the 6 days at 47.92 kg/cm^2 and significantly different from all combination treatments. Meanwhile, the lowest fruit hardness was obtained in the combination without treatment (control) and using the level of maturity after physiological mature (P_0T_s) from 3 to 6 days of storage with a hardness on the 6 days of 2.91 kg/cm^2. The percentage difference in hardness between the two combinations is 94.895% (Table 3). This is supported by the results of research by Usmayani et al. [9] showed that papaya fruit harvested at the level of physiological mature maturity were stored for 0 days (T_k) with an application of $KMnO_4$ the highest concentration (30%) was able to provide the best hardness value until the 7 days, and the next day it decreased. The results of research by Kurniawan [10] also stated that with various treatments of chitosan as an ethylene oxidizer, where the higher the levels of chitosan given the better the visual and physical quality of the fruit.

3.4 Vitamin C content

The highest vitamin C content at nine days of storage was found in P_3 which was 23.08 mg/100 g and the lowest is P_0 of 20.34 mg/100 g although not significantly different from P_1 and P_2 (Table 5). This is supported by the results of research by Windasari [11] which states that the vitamin C content will continue to decrease along with the ripening process due to respiration activity. This is also in accordance with Windasari [11] where the fruit treated with $KMnO_4$ provided higher vitamin C content compared to the control treatment. At the maturity level, T_k gave the lowest vitamin C content of 15.74mg/100 g and the highest was T_s of 27.28 mg/100 g. The highest vitamin C content occurs when the fruit is ripe [12].

Table 3 Interaction between the Use of Potassium Permanganate (P) Concentration and Maturity Level (T) on Fruit Hardness Variables (kg/cm2)

Concentration of $KMnO_4$	**Maturity Level**		
	T_k	**T_m**	**T_s**
	.... Fruit hardness (kg/cm2) 3 das....		
P_0	39.67 b	12.00 ef	6.97 f
P_1	51.98 a	12.48 ef	8.29 f
P_2	54.33 a	12.54 def	8.57 f
P_3	57.00 a	17.50 cde	10.07 f
	.... Fruit hardness (kg/cm2) 6 das....		
P_0	19.55 d	4.91 e	2.91 e
P_1	30.67 c	9.82 e	4.98 e
P_2	39.67 b	7.64 e	4.64 e
P_3	47.92 a	6.63 e	6.05 e

Description: Numbers followed by the same letter in a column show no significant difference in Duncan's 5% multiple-spaced test

Table 4 Single Factor Results Using the Concentration of Potassium Permanganate (P) and Maturity Level (T) on Fruit Hardness Variables (kg/cm2)

Treatment	Storage Time
	9 das
Concentration of $KMnO_4$	.....kg/cm2.....
P_0	3.22 d
P_1	10.07 a
P_2	5.08 b
P_3	4.43 c
BNT 5%	2.811
Maturity Levels	.....kg/cm2.....
T_k	9.61 a
T_m	4.87 b
T_s	2.61 c
BNT 5%	2.434

Description: Numbers followed by the same letter in the same treatment and column show no significant difference in the 5% level of low significant difference test (LSD); ns: not significantly different

Table 5 Single Factor Results Using Concentration of Potassium Permanganate (P) and Maturity Level (T) of Vit C Levels Test Variables 9 days after storage

Treatment	Vitamin C content
Concentration of $KMnO_4$	.....mg/100g.....
P0	20.34 a
P1	21.12 a
P2	22.94 a
P3	23.08 a
BNT 5%	7.198
Maturity Level	.....mg/100g.....
Tk	15.74 a
Tm	22.59 b
Ts	27.28 c
BNT 5%	6.234

Description: Numbers followed by the same letter in the same treatment and column show no significant difference in the 5% level of low significant difference test (LSD); ns: not significantly different

4 Conclusion

The **$KMnO_4$** concentration of 105 mg/100 ml of water gave the lowest increase in weight loss of 19.58%, the lowest decrease in water content of 1.5%, and the best vitamin C content. The level of physiological immature fruit gave the lowest increase in weight loss of 53.03% and the lowest decrease in water content of 1.7%. The interaction between the two treatments showed an interaction between fruit weight at 3, 6, and 9 days of storage and fruit hardness at 3 and 6 days of storage.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that there is no conflict of interest.

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