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Ethylene Oxidizing Wrappers for Postharvest Storage of Raja Bulu Banana: Non-Destructive Assessment of Shelf Life and Quality

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Abstract. This study aimed to test the effectiveness of gauze and nylon fiber wraps containing ethylene oxidizing compounds, namely clay mixed with potassium permanganate ($KMnO_4$), in extending the shelf life of Raja Bulu bananas (Musa sp., AAB Group). The experiment was conducted at the Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, from February to March. A randomized complete design (RCD) with seven treatments was applied: P1 as control without wrapping or oxidizing materials; P2, P3, and P4 using gauze with 30, 60, and 90 g oxidizing compounds; and P5, P6, and P7 using nylon fibers with 30, 60, and 90 g oxidizing compounds. Each compound consisted of clay and $KMnO_4$ in predetermined proportions. The results showed that the longest shelf life, reaching 14 days, was obtained from P5 treatment, where the bananas remained edible. Similar results were observed in P3 and P4 gauze treatments, while bananas in P1 and P7 spoiled after nine days. Wrapping with ethylene oxidizing compounds reduced fruit weight loss during 3–12 days of storage, with P5 showing the lowest loss after 12 days. However, the treatments did not affect the skin color scale index, fruit flesh-to-skin ratio, edible portion, or skin firmness. Overall, ethylene oxidizing wraps extended banana shelf life by up to five days compared with the control. Nylon fiber wrapping with 30 g oxidizing compound is recommended for Raja Bulu banana storage. This treatment offers a practical and low-cost postharvest technology for maintaining banana quality during short-term distribution processes.

Keywords: Ethylene Oxidizing Compounds; Fruit; $KMnO_4$; Shelf Life; Wrapping Materials.

1. INTRODUCTION

Banana (*Musa sp.*) is one of Indonesia's leading fruit commodities, contributing substantially to both domestic consumption and international trade. National production has shown steady growth, reaching approximately 7.2 million tons in 2015 and increasing to 8.5 million tons by 2025 (BPS, 2025; FAOSTAT, 2024). Despite this large production potential, export volumes remain relatively low, averaging below 10,000 tons annually, with reported figures of 4,800 tons in 2015, 7,100 tons in 2021, and 7,200 tons in 2025 (Ministry of Agriculture, 2025). This disparity reflects the predominance of domestic market absorption and the persistent challenge of meeting international quality standards, including fruit uniformity, postharvest handling, and phytosanitary requirements. Recent policy initiatives, such as the promotion of Good Agricultural Practices (GAP) and improved postharvest technologies, have been introduced since 2020 to enhance competitiveness (FAO, 2021; BPS, 2023). However, Indonesia's banana exports continue to lag behind production growth, underscoring the need for integrated strategies to align production potential with global market demands.

Various banana cultivars are cultivated in Indonesia, among which Raja Bulu (*Musa sp.*, AAB Group) is a prominent type of medium-sized dessert banana. The fruit is cylindrical and slightly curved, with a rounded base and thick yellow peel speckled with brown spots. The pulp is seedless, soft in texture, and notably sweet, with a soluble solids content of 28–30 °Brix, and

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displays a reddish-yellow coloration. Individual fruits measure 16–17 cm in length and weigh approximately 175–185 g. Each bunch typically consists of 5–7 hands, with 14–15 fruits per hand, and is harvested 10–12 months after planting (PKBT, 2008). Raja Bulu has been officially released as an improved cultivar by the Indonesian government. The fruits are relatively large, with an average diameter of 3.2 cm and bunch weights ranging from 12–16 kg. When fully ripe, the pulp develops a reddish-yellow hue, offering a sweet, rich flavor and a distinctive aroma (Sobir, 2009; Hapsari & Lestari, 2016; FAO, 2021).

Horticultural products, including bananas, are generally perishable, easily damaged, and voluminous. This is largely attributed to the high respiration rate and endogenous ethylene production during fruit ripening, particularly under tropical conditions with relatively warm temperatures. The ripening process involves both physical and chemical changes. Physical changes that reduce fruit quality include alterations in color, texture, weight loss, wilting, and wrinkling. Chemical changes involve modifications in carbohydrate composition, organic acids, and aroma profiles (Santoso & Purwoko, 1995; Wills et al., 2016; Yahia & Carrillo-López, 2019).

To extend the shelf life of fruit, appropriate storage technologies are required to mitigate quality deterioration and reduce postharvest losses. A simple technique that can be applied to slow down quality decline in bananas is the use of clay mixed with potassium permanganate ($KMnO_4$) as an ethylene oxidizing agent. Treatment with 50 g of the oxidizing compound (46.25 g clay + 3.75 g $KMnO_4$) per 1.03 kg of Raja Bulu bananas *(*Musa sp., AAB Group) was reported to prolong storage life by nine days compared with the control, while maintaining peel color and reducing weight loss more effectively than treatments with 10 g or 30 g of ethylene absorbent (Kholidi, 2009). Further research is needed to develop more practical approaches, particularly through the use of ethylene-oxidizing wrapping materials with optimized compound weights (clay + $KMnO_4$), to extend the freshness and storage duration of Raja Bulu bananas. Wrapping is essential to prevent direct contact between the oxidizing agents and the fruit, which could otherwise compromise product quality (Wills et al., 2016; Yahia & Carrillo-López, 2019).

The wrapping materials used for ethylene absorption should ideally possess low density, limited absorption capacity, yet high retention ability for $KMnO_4$ (Pantastico et al., 1989). In addition, the wrapping fibers must be of good quality, stable, and inert, ensuring that they do not react with or interfere with the treatment (Matcha, 2010). In this study, gauze cloth and nylon fibers were employed as wrapping materials, combined with $KMnO_4$ at weights ranging from 2.25 to 6.75 g for Raja Bulu bananas *(*Musa sp., AAB Group). This range was selected based on previous findings (Kholidi, 2009), which reported that 3.75 g of $KMnO_4$ could extend the shelf life of Raja Bulu bananas by nine days compared with untreated fruit. The objective of this research was to evaluate the effectiveness of bandage and nylon fibers as wrapping materials for ethylene oxidizing agents, and to determine the optimal weight of the oxidizing compound (clay + $KMnO_4$) for postharvest storage of Raja Bulu bananas.

2. THEORITICAL REVIEW

Banana (*Musa* sp.) is a climacteric fruit that undergoes rapid physiological changes during ripening, driven by high respiration rates and endogenous ethylene production. Ethylene acts as a key regulator of ripening processes, stimulating enzymatic activities that alter peel color, soften texture, and modify carbohydrate and organic acid composition (Santoso & Purwoko, 1995; Wills et al., 2016). These changes accelerate postharvest deterioration, particularly under tropical conditions, resulting in reduced shelf life and economic losses. Understanding the physiological role of ethylene is therefore fundamental to developing effective postharvest storage technologies.

To mitigate ethylene-induced deterioration, several management strategies have been explored. Potassium permanganate ($KMnO_4$) is widely recognized as an effective ethylene oxidizing agent, converting ethylene into carbon dioxide and water, thereby reducing its concentration in storage environments (Pantastico et al., 1989). Compared with synthetic inhibitors such as 1-Methylcyclopropene (1-MCP), $KMnO_4$ remains popular in tropical fruit systems due to its affordability and ease of application (Sisler & Serek, 2003; Yahia & Carrillo-López, 2019). However, direct contact between $KMnO_4$ and fruit can negatively affect quality, necessitate encapsulation or wrap to ensure safe and controlled application.

Wrapping materials play a critical role in the effectiveness of ethylene oxidizing agents. Ideal materials should possess low density, limited absorption, but high retention capacity for $KMnO_4$, while being chemically stable and inert (Pantastico et al., 1989; Matcha, 2010). Gauze cloth and nylon fibers have been identified as suitable candidates, offering fiber stability and permeability that allow controlled release of oxidizing compounds without contaminating the fruit. Previous studies demonstrated that 3.75 g $KMnO_4$ combined with clay extended the shelf life of Raja Bulu bananas by nine days compared with untreated controls (Kholidi, 2009). These findings highlight the potential of optimized wrapping systems to enhance postharvest storage.

Despite promising results, research gaps remain in determining the comparative effectiveness of different wrapping materials and the optimal weight of oxidizing compounds for specific cultivars such as Raja Bulu. Recent studies emphasize the need for practical, scalable technologies that balance efficacy with safety and cost efficiency (Wills et al., 2016; Yahia & Carrillo-López, 2019). Addressing these gaps is essential to strengthen Indonesia's banana supply chain, reduce postharvest losses, and improve competitiveness in international markets. Thus, this study builds upon established postharvest physiology and ethylene management principles to evaluate gauze and nylon fiber wrappings with varying $KMnO_4$ loads for extending the shelf life of Raja Bulu bananas.

3. RESEARCH METHODS

This study was conducted at the Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, from February to March.

The primary material used in this study was Raja Bulu bananas (*Musa* sp., AAB Group), harvested at three-quarters maturity from Ciampea Market, Bogor. The treatment materials included saturated potassium permanganate ($KMnO_4$) solution, clay obtained from Cikarawang Village, gauze, nylon fibers, cardboard boxes, transparent plastic, 5 g silica gel, newspaper. The instruments employed consisted of an oven and analytical balance.

The research design used was a randomized completely design (RCD). It consisted of seven treatments, namely: P1: Control (no wrapping material and no ethylene oxidizing agent); P2: Gauze + 30 g of ethylene oxidizing agent (27.75 g of clay + 2.25 g of $KMnO_4$); P3: Gauze + 60 g of ethylene oxidizing agent (55.5 g of clay + 4.5 g of $KMnO_4$); P4: Gauze + 90 g of ethylene oxidizing agent (83.25 g of clay + 6.75 g of $KMnO_4$); P5: Nylon fiber + 30 g of ethylene oxidizing agent (27.75 g of clay + 2.25 g of $KMnO_4$); P6: Nylon fiber + 60 g of ethylene oxidizing agent (55.5 g of clay + 4.5 g of $KMnO_4$); P7: Nylon fiber + 90 g of ethylene oxidizing agent (83.25 g of clay + 6.75 g of $KMnO_4$).

The experiment consisted of preparation, packaging and storage, sampling, and observation. The experiment consisted of seven treatments, with each treatment consisting of three replicates, resulting in 21 experimental units. Each experimental unit consisted of two half-combs of banana. Analysis of variance used the F-test, and if a significant effect was found, Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level.

Observations were conducted using two half-hands of bananas per experimental unit. Each half-hand contained approximately seven fingers and was allocated for either non-destructive measurements. Non-destructive observations included shelf life, fruit weight loss, fruit skin color, and fruit hardness recorded at 3, 6, 9, and 12 days after treatment (DAT).

Shelf life, the parameters used to estimate shelf life involve observing physical changes in bananas, particularly changes in the fruit's color scale index. Fruit weight loss was measured by comparing the weight of the bananas before treatment and at the time of observation. Fruit weight loss was measured using an analytical balance in grams (g). The formula used was:

$$\% \text{ Fruit weight loss} = \frac{\text{Initial weight} - \text{Obseravation weight}}{\text{Initial weight}} \times 100\%$$

The skin color scale index for Raja Bulu bananas (*Musa sp.* AAB Group) has been used as a guide to determine the ripening stages of the fruit. The skin color scale index for Raja Bulu bananas is assumed to correspond to the distribution of green and yellow colors in Cavendish bananas. According to Kader (2008), the degree of skin yellowing is rated on a scale of 1 to 8. The values for the degree of yellowing of the fruit skin are: 1: Green, 2: Green with a hint of yellow, 3: Yellowish-green, 4: More yellow than green, 5: Yellow with green tips, 6: Fully yellow, 7: Yellow with a few brown spots, 8: Yellow with more extensive brown spots.

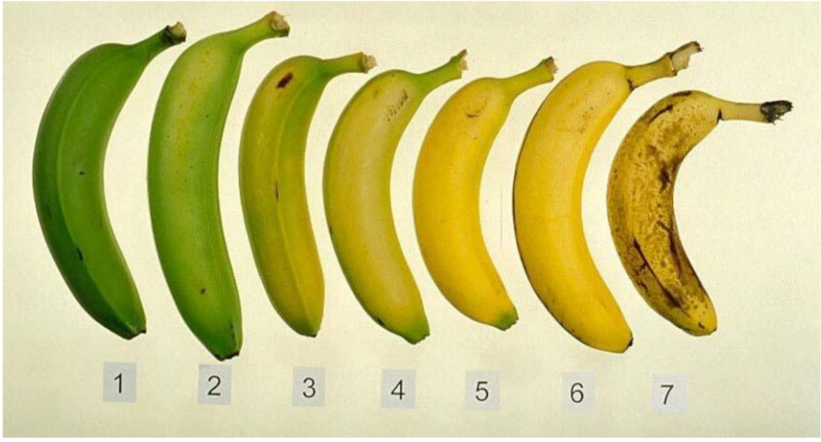

Figure 1. Banana Skin Color Scale Maturity Index.

4. RESULTS AND DISCUSSION

Shelf Life

The use of wrapping materials containing ethylene oxidizing agents was effective in extending the shelf life of Raja Bulu bananas compared with the control treatment. Significant differences were observed among treatments P2–P7 in their effects on fruit storage duration (Table 1). Treatments combining gauze or nylon fibers with varying weights of clay + $KMnO_4$ demonstrated improved performance in maintaining fruit quality, indicating that both the type of wrapping material and the dosage of oxidizing agents influenced postharvest longevity.

Tabel 1. Shelf Life of Raja Bulu Banana (*Musa sp.*, AAB Group*)* During Storage.

Treatments	Shelf life (DAT)*
P1: Control	9d
P2: Gauze + 30 g of ethylene oxidizing agent	11bcd
P3: Gauze + 60 g of ethylene oxidizing agent	12abc
P4: Gauze + 90 g of ethylene oxidizing agent	13ab
P5: Nylon fiber + 30 g of ethylene oxidizing agent	14a
P6: Nylon fiber + 60 g of ethylene oxidizing agent	10cd
P7: Nylon fiber + 90 g of ethylene oxidizing agent	9d

*Note: *Numbers followed by the same letter are not significantly different according to the DMRT test at the 5% level; DAT (Day After Treatment).*

Table 1 shows that the control treatment (P1, without ethylene oxidizer) and the treatment with 6.75 g $KMnO_4$ in nylon fibers (P7) were only able to maintain banana quality for up to nine days of storage. Fruits in both treatments exhibited symptoms of anthracnose, characterized by reddish-brown speckled lesions across the peel surface, particularly concentrated at the middle and distal ends of the fruit. According to Eckert (1975, cited in Pantastico, 1989), severe postharvest damage in bananas is commonly caused by fungal infections such as anthracnose, crown rot, and stem-end rot. *Gloeosporium musarum* often infects wounds on the pedicel or peel surface, producing the typical anthracnose symptoms observed in this study.

Additional disease symptoms, notably crown end rot, appeared after 12 days of storage, localized around the crown and basal portions of the fruit. Turner (cited in Mitra, 1997) reported that crown end rot and anthracnose (*Colletotrichum musae*) are the major postharvest pathogens affecting bananas worldwide. The presence of these diseases in untreated and high-dose nylon treatments highlights the vulnerability of bananas to fungal infection when ethylene oxidizer application is ineffective or improperly managed.

The longest shelf life**,** 14 days of storage, was achieved with treatment P5 (2.25 g $KMnO_4$ in nylon fibers). This was followed by P4 (6.75 g $KMnO_4$ in gauze, 13 days), P3 (4.50 g $KMnO_4$ in gauze, 12 days), P2 (2.25 g $KMnO_4$ in gauze, 11 days), and P6 (4.50 g $KMnO_4$ in nylon fibers, 10 days). Statistical analysis indicated no significant difference between P5, P4, and P3, suggesting that both nylon and gauze wrappings can be effectively used as carriers for $KMnO_4$ when combined with clay powder.

These findings demonstrate that wrapping materials (gauze and nylon fibers) combined with $KMnO_4$ oxidizers are capable of extending the shelf life of Raja Bulu bananas compared with the control. The results also emphasize that optimal $KMnO_4$ dosage is critical, as excessively high concentrations may not provide additional benefits and may even coincide with increased disease incidence. Thus, the use of gauze or nylon fiber wrappings with moderate $KMnO_4$ loads represents a practical approach to prolonging postharvest storage and maintaining fruit quality.

Fruit Weight Loss

The use of ethylene-oxidizing packaging significantly inhibited weight loss in Raja Bulu bananas at 3 and 6 days post-harvest and was significant at 9 and 12 days post-harvest compared to the control treatment. Weight loss increased with the duration of storage (Table 2).

Table 2. Weight Loss of Raja Bulu Banana (*Musa sp.*, AAB Group) During Storage.

Treatments	Weight Loss			
	3 DAT	6 DAT	9 DAT	12 DAT
P1: Control	0.77d	1.63c	2.81b	4.04b
P2: Gauze + 30 g of ethylene oxidizing agent	0.95cd	1.79c	2.69b	3.76b
P3: Gauze + 60 g of ethylene oxidizing agent	1.63a	2.80a	3.77a	4.77ab
P4: Gauze + 90 g of ethylene oxidizing agent	1.39ab	2.51ab	3.42ab	4.19b
P5: Nylon fiber + 30 g of ethylene oxidizing agent	1.04bcd	1.99bc	2.94b	3.85b
P6: Nylon fiber + 60 g of ethylene oxidizing agent	1.23abc	2.17abc	3.29ab	6.92b
P7: Nylon fiber + 90 g of ethylene oxidizing agent	1.54a	2.64ab	3.76a	6.27a

*Note: *Numbers followed by the same letter are not significantly different according to the DMRT test at the 5% level; DAT (Day After Treatment).*

At the early stages of storage (3–6 days after treatment, DAT), the control treatment (P1) exhibited the smallest weight loss, ranging from 0.77% at 3 DAT to 1.63% at 6 DAT (Table 2). However, after six days of storage, the treatments with ethylene oxidizing agents in nylon fibers (P5 and P6) showed weight loss values that were not significantly different from the control. This indicates that the application of $KMnO_4$ encapsulated in nylon fibers was able to maintain fruit weight comparable to untreated bananas during the initial storage period.

By 12 DAT, only three treatments (P3–P5) remained viable. Among these, treatment P5 (2.25 g $KMnO_4$ in nylon fibers) demonstrated the lowest weight loss, although statistical analysis revealed no significant differences compared with P3 (4.50 g $KMnO_4$ in gauze) and P4 (6.75 g $KMnO_4$ in gauze). These findings suggest that both gauze and nylon fibers can serve as effective wrapping materials for $KMnO_4$, with moderate dosages providing optimal performance in reducing fruit weight loss.

Weight loss during storage is primarily caused by the loss of water through transpiration. Respiration and transpiration continue after harvest, as the fruit is physiologically detached from its source of water, photosynthates, and minerals. Consequently, bananas rely solely on their internal reserves to sustain metabolic processes. The depletion of substrates through respiration, without replenishment, leads to progressive deterioration of fruit quality (Santoso & Purwoko, 1995).

Overall, the results highlight that ethylene oxidizer treatments encapsulated in gauze or nylon fibers can effectively reduce weight loss compared with untreated fruit, particularly when applied at moderate $KMnO_4$ concentrations. This supports the role of controlled ethylene management in extending shelf life and maintaining postharvest quality of Raja Bulu bananas (*Musa* sp., AAB Group).

Fruit Skin Color

The use of ethylene-oxidizing packaging materials did not affect the fruit color scale index during storage. The use of packaging materials showed no difference in maintaining skin color changes compared to the control until the end of storage (Figure 2). Initially (3–6) HSP, the treatment with 4.5 g $KMnO_4$ in gauze (P3) appeared to better maintain color changes, and there were no significant differences compared to P2, P4–P7 (Figure 2). However, at (9–12) HSP, all treatments showed the same fruit skin color scale. It is suspected that all treatments were able to oxidize ethylene effectively. This resulted in the inhibition of the ripening process, so that the fruit color remained unchanged during storage.

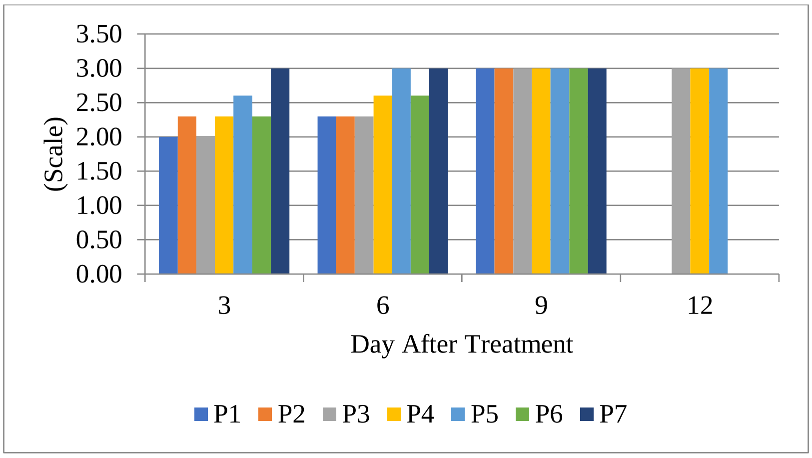

Figure 2. Effect of Ethylene-Oxidizing Treatments on Peel Color of Pisang Raja Bulu During Storage.

During storage, the peel color index of bananas changed progressively, reflecting the ripening process. Peel color was assessed using an eight-point scale ranging from 1 (green) to 8 (yellow with extensive brown spots), as described by Kader (2008) in Figure 1. At the beginning of storage, bananas across all treatments exhibited values within the 1–3 range, corresponding to green, green with slight yellow, and greenish-yellow stages. Over time, peel color advanced toward darker greenish-yellow and eventually yellowish-black hues.

The observed changes are consistent with the natural ripening sequence of bananas. According to Simmonds (1987), banana peel color transitions from dark green to light green and finally to yellow as ripening progresses. This process is driven by chlorophyll degradation, with chlorophyll concentrations declining from approximately 50–100 mg/kg in green peel to nearly zero at full maturity. The loss of chlorophyll is accompanied by the unmasking of carotenoids, which impart the characteristic yellow color of ripe bananas.

These findings confirm that peel color index is a reliable indicator of ripening and storage duration. Treatments with ethylene oxidizing agents (gauze or nylon fibers combined with $KMnO_4$) delayed the progression of peel color compared with the control, thereby extending the visual freshness of bananas. The slower transition in treated fruit suggests that ethylene oxidation effectively reduced the rate of chlorophyll breakdown, contributing to prolonged shelf life and improved postharvest quality.

Fruit Skin Hardness

The packaging material for ethylene oxidizers did not affect the skin firmness of bananas during storage. The use of wrapping materials showed no difference in maintaining fruit skin firmness compared to the control (Table 3). These results indicate that both nylon fiber and gauze can be used as wrapping materials for $KMnO_4$ with a clay powder carrier to extend the shelf life of Raja Bulu bananas.

In general, the skin firmness of bananas continues to decrease with the duration of storage. This indicates that as the fruit ripens, it is approaching its peak ripeness. The decrease in skin firmness is indicated by an increasing penetrometer scale reading (Table 3).

Table 3. Fruit Skin Hardness of Raja Bulu Banana (Musa sp., AAB Group) During Storage.

Tretaments	Fruit Skin Hardness (mm/50 g/5 second)	
	6 DAT	12 DAT
P1: Control	32.40	69.43
P2: Gauze + 30 g of ethylene oxidizing agent	30.47	133.67
P3: Gauze + 60 g of ethylene oxidizing agent	35.13	96.33
P4: Gauze + 90 g of ethylene oxidizing agent	51.80	75.57
P5: Nylon fiber + 30 g of ethylene oxidizing agent	36.17	97.10
P6: Nylon fiber + 60 g of ethylene oxidizing agent	34.43	116.43
P7: Nylon fiber + 90 g of ethylene oxidizing agent	31.90	143.67

According to Pantastico et al. (1989), the reduction in fruit firmness during storage is closely related to changes in pectic substances. As fruit develops, the amount of insoluble protopectin decreases, while soluble pectates and pectinates increase. This transformation alters the integrity of the middle lamella and cell walls, leading to softening of the tissue. The degradation of protopectin into soluble forms is a key biochemical process that marks the transition from unripe to ripe stages in bananas.

Sholihati (2004) further explained that the mechanism of firmness reduction involves the breakdown of major cell wall components, including cellulose, hemicellulose, pectin, and lignin. The enzymatic hydrolysis of pectic acids (pectinic and pectic acid) weakens the structural framework of the cell wall, resulting in progressive loss of firmness. This process is accelerated by ethylene production during ripening, which stimulates the activity of cell wall-modifying enzymes such as polygalacturonase and pectin methylesterase.

Ratio of Fruit Flesh to Fruit Skin and Edible Portion

The use of wrapping materials containing ethylene oxidizing agents did not significantly affect the pulp-to-peel ratio or the edible portion of bananas during storage. Statistical analysis showed no differences between treatments with gauze or nylon fiber wrappings compared with the control (Table 4). These findings indicate that both nylon fibers and gauze cloth can be effectively used as carriers for $KMnO_4$ with clay powder to extend shelf life, without altering the natural progression of pulp and peel weight distribution.

At the beginning of storage, bananas exhibited relatively low pulp weight and high peel weight. As storage progressed and ripening advanced, pulp weight increased while peel weight decreased, resulting in a larger edible portion. This shift reflects the physiological changes associated with ripening, where water content in the pulp increases while peel tissues lose moisture.

According to Diennazola (2008), correlation analysis between pulp-to-peel ratio and edible portion revealed a positive relationship. This occurs because water migrates from the peel into the pulp during storage, leading to reduced peel weight and increased pulp weight. Consequently, the edible portion of the fruit becomes larger as ripening continues.

Table 4. Changes in the Fruit Flesh to Fruit Skin Ratio and the Edible Portion of the Raja Bulu Banana (Musa sp., AAB Group) During Storage.

Tretaments	Fruit Flesh to Fruit Skin Ratio		Edible Portion (%)	
	6 DAT	12 DAT	6 DAT	12 DAT
P1: Control	0.73	0.61	41.96	37.66
P2: Gauze + 30 g of ethylene oxidizing agent	0.78	0.73	43.66	41.19
P3: Gauze + 60 g of ethylene oxidizing agent	0.75	0.72	42.75	41.53
P4: Gauze + 90 g of ethylene oxidizing agent	0.89	1.01	46.99	50.05
P5: Nylon fiber + 30 g of ethylene oxidizing agent	0.87	0.83	46.52	45.08
P6: Nylon fiber + 60 g of ethylene oxidizing agent	0.81	0.77	44.60	43.13
P7: Nylon fiber + 90 g of ethylene oxidizing agent	0.90	0.73	47.44	41.06

According to Simmonds (1966, cited in Pantastico, 1989), the reduction in peel weight during ripening is associated with the conversion of cellulose and hemicellulose in the peel into starch. This biochemical transformation contributes to the gradual decline in peel mass as bananas mature. The process reflects the structural and compositional changes in peel tissues that occur during postharvest storage.

Lodh (1971, cited in Pantastico, 1989) further explained that the increase in the pulp-to-peel ratio is driven by changes in sugar content within both tissues. Sugar concentration in the pulp rises more rapidly than in the peel due to increased osmotic pressure, which facilitates water migration from the peel into the pulp. This transfer of water results in reduced peel weight and increased pulp weight, thereby altering the balance between the two components.

5. CONCLUSION AND RECOMMENDATION

The longest fruit shelf life (14 days of storage) was achieved with the treatment of 2.25 g KMnO4 in nylon fiber (P5), and the fruit was still safe for consumption; however, there was no significant difference compared to the treatments of 6.75 g KMnO4 in gauze (P4) and 4.50 g KMnO4 in gauze (P3). Bananas in the control treatment (without an ethylene oxidizer) (P1) and the treatment with 6.75 g of $KMnO_4$ in nylon fiber (P7) were unfit for consumption after 9 days of storage. The ethylene oxidizer wrapping treatment (clay + $KMnO_4$) reduced banana weight loss at 3, 6, 9, and 12 days of storage. After 12 days of storage, among the three treatments that remained viable, the treatment with 2.25 g $KMnO_4$ in nylon fiber (P5) showed the smallest weight loss.

The ethylene oxidizer wrapping treatment did not affect the skin color scale index, the fruit flesh-to-skin ratio, the edible portion, skin firmness. Ethylene oxidant treatment with both types of wrapping materials can extend fruit shelf life by 5 days compared to the control. Thus, the use of nylon fiber wrapping material with 30 g of ethylene oxidant is recommended for the storage of Raja Bulu bananas (Musa sp. AAB Group).

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