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OPTIMIZING TECHNICAL AND ECONOMIC EFFICIENCY: PLASTIC PACKAGING ANALYSIS FOR MINIMIZING VEGETABLE LOSSES AT MOJOSARI MARKET IN MOJOKERTO DISTRICT

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ABSTRACT

The study aimed to assess the technical and economic impact of plastic packaging on reducing vegetable yield losses and enhancing economic value. Conducted in Mojokerto at room temperature using research materials sourced deliberately from the Mojosari market, both primary and secondary data were collected through observation. Technical efficiency was analyzed by calculating the KHS ratio, alongside economic efficiency analysis. Results showed a significant reduction in Vegetable Yield Losses with plastic packaging: mustard (0.403%), carrots (1.352%), and beans (1.826%) compared to treatments without plastic packaging: carrots (49.862%), beans (50.575%), and mustard (51.159%). Plastic packaging demonstrated superior technical efficiency in vegetable storage. Economically, the use of plastic packaging maintained higher economic values for vegetables: mustard (Rp. 4.980,-), carrots (Rp. 4.932,-), and beans (Rp. 4.909,-), compared to treatments without plastic packaging: carrots (Rp. 501,-), beans (Rp. 494,-), and mustard (Rp. 488,-). Thus, plastic packaging proved to be both technically and economically efficient in preserving horticultural vegetables.

Keywords: economic efficiency; technical efficiency; vegetable packaging; yield loss.

INTRODUCTION

Vegetables are among the post-harvest products of horticulture that undergo quality deterioration characterized by rapid decay processes. The primary cause of this decay is the high transpiration or water evaporation rates occurring through natural openings such as stomata, hydathodes, and lenticels found on the surface of leafy vegetable products (Mangaraj & Goswami, 2009; Mishra & Gamage, 2007). Proper packaging and storage methods are crucial to maintaining quality and extending shelf life by inhibiting deterioration. Packaging serves as a means of providing suitable surroundings for food items and thus demands significant thought and attention (Sangadji et al., 2020). Cabbage, a vegetable with high economic value, is susceptible to yield loss during storage due to damage or environmental influences. One effective method to mitigate cabbage yield loss is by utilizing efficient plastic packaging (Gonzales & Acedo Jr, 2016; Munhuewyi, 2012; Opara, 2013). Plastic packaging plays a vital role in preserving the quality and cleanliness of cabbage produce over an extended period, thereby reducing yield loss and enhancing its economic value. However, excessive use of plastic packaging can have negative environmental impacts.

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The global issue of reducing food loss and waste (FLW) has garnered significant public attention as part of efforts to combat global hunger and enhance food security (Chaboud & Daviron, 2017; Sethi et al., 2020; Shafiee-Jood & Cai, 2016). Studies led by various international and national organizations, including the FAO, reveal that approximately one-third of all food produced on the planet, including around half of all fruits and vegetables (F&V), is lost or remains unconsumed. FLW occurs across five key stages of the food supply chain: agricultural production, post-harvest handling and storage, processing, distribution, and consumption. In developed countries, the majority of FLW occurs during retail and consumption, primarily due to logistical management operations and consumer behavior. In response, the United Nations set ambitious goals in September 2015 to halve global per capita food waste by 2030, a commitment adopted by numerous countries (Capone et al., 2016; Telesetsky, 2013).

Shallots, seasonal plants with relatively small storage spaces, often face significant quality and quantity losses during storage. Storing shallot bulbs presents a challenge in tropical countries like India, where storage methods significantly influence the quality and post-harvest life of shallots. Dehydration emerges as a significant concern during post-harvest storage, transportation, and sales, impacting commodity value. Studies utilizing low-field nuclear magnetic resonance (LF-NMR) to analyze the dehydration process of golden passion fruit during storage reveal insights into water loss and quality decline dynamics. The findings underscore the importance of mitigating severe dehydration, which not only leads to weight and freshness loss but also triggers physiological metabolism changes, cellular and tissue structure alterations, and accelerates quality decline. Bananas, particularly the Nendran variety, are subject to significant post-harvest losses in markets, often due to rotting diseases and inadequate handling. Similarly, Asian pears face challenges related to post-harvest losses and quality decline, necessitating effective post-harvest management strategies. Tomatoes, highly perishable horticultural fruits, experience increased weight loss attributed to their high respiration rate, impacting overall quality and consumer acceptance.

Efforts to address post-harvest losses and improve the quality and safety of fresh produce require comprehensive supply chain analysis and the implementation of effective post-harvest management systems. Such interventions are crucial for minimizing post-harvest losses and ensuring food security. Moreover, understanding the technical and economic efficiency of plastic packaging in reducing vegetable yield loss during storage is essential for enhancing the economic value of vegetable sales. Thus, further research into the efficacy of plastic packaging usage in mitigating post-harvest losses is warranted to inform sustainable agricultural practices and food security initiatives.

LITERATURE REVIEW

Technical and Economic Efficiency

Technical efficiency refers to the ability of a system or process to produce maximum output through the efficient use of available resources. This concept is often employed in economic and operations management contexts. In economics, technical efficiency can be measured by comparing the inputs required to produce a certain output. When a system or process achieves high technical efficiency, it means that with the same amount of input, they can generate a greater output compared to less efficient systems or processes.

According to Zulkarnain et al. (2022), efficiency arises because resources to meet human needs are limited, thus sacrificing minimal costs by producing optimal outputs. In contrast to technical efficiency, from an economic perspective, efficiency can be interpreted as the economic benefit of using plastic packaging exceeding the costs incurred. According to Purbata et al. (2020), economic efficiency is the result of the combination of technical efficiency and allocation efficiency, meaning that farmers with high technical and allocation efficiency have high economic efficiency. Economic efficiency is achieved when production factors are used to produce a predetermined amount of output with predetermined costs for maximum profit.

Yield Loss

Currently, nearly 50% of fruits and vegetables are lost during production or storage. Biological control of rot diseases and storage remains inadequate. New multi-omic technologies now enable studying microbiomes and their responses at the community level, which will help advance current classical approaches and develop more efficient and robust microbiome-based approaches for fruit and vegetable storage, quality solutions, and safety. Weather is a major factor in crop loss as it can significantly affect product appearance and thus marketability in the food retail sector. Effective measures to reduce food loss include protective planting in greenhouses or under rain and hail-resistant nets, sustainable cooling systems, better packaging, and staff training.

The post-harvest handling of vegetable commodities is crucial for maintaining the quality and freshness of harvested produce in the hands of consumers. Until now, traded vegetables are often left unpacked or poorly arranged, accelerating the deterioration of their quality. Therefore, a new habit pattern in handling vegetables is needed to ensure their quality, such as the use of plastic packaging to reduce vegetable weight loss during presentation or storage in vegetable trading businesses.

Food Safety

Food safety (also known as food hygiene) is protected by hazard analysis and critical control points or HACCP (Kamboj et al., 2020; Mortlock et al., 1999). This analysis uses systematic prevention methods to protect food and consumers from chemical, physical, and biological contamination. It is usually employed during production and post-production processes to ensure no existing contaminants make the product unsafe and to design procedures to reduce contaminant risks to safe levels.

According to Awuchi (2023), food safety is crucial for social well-being and human health. Staple foods continue to be the main source of nutritional intake, although dietary diversity can reduce health risks to some extent. More than half of the world's population consumes rice; however, compared to other crops, rice is more susceptible to pollution. Heavy metals in concentrations below the MAC can still pose health risks. Long-term exposure to low concentrations of arsenic can cause non-carcinogenic diseases such as hypertension, nerve disorders, and even cancer. Risk assessment should consider various factors such as age, weight, eating habits, and long-term intake.

Based on the literature review, the hypothesis proposed in this study is that there is a significant difference in vegetable weight loss during storage between the group using plastic packaging and the group not using plastic packaging.

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METHODS

The research method employed in this study is quantitative methodology. According to Sangadji et al. (2022) quantitative methodology involves the utilization of numerical data to address research questions. This numerical data is acquired through measurements and can be analyzed using statistics, as per the predetermined research design. Hence, this study adopts a Randomized Complete Design (RCD) research design comprising two treatments: plastic packaging and no plastic packaging, with the following composition:

1. Treatment A = Ten (10) units of cabbage packaged in plastic, each with a sample weight of +500 grams.
2. Treatment B = Ten (10) units of carrots packaged in plastic, each with a sample weight of +500 grams.
3. Treatment C = Ten (10) units of green beans packaged in plastic, each with a sample weight of +500 grams.
4. Treatment D = Three (3) units of unpackaged cabbage, each with a weight of +500 grams.
5. Treatment E = Three (3) units of unpackaged carrots, each with a weight of +500 grams.
6. Treatment F = Three (3) units of unpackaged green beans, each with a weight of +500 grams.

The general formula to calculate the t-value in testing the difference between two means is as follows: t = (mean1 - mean2) / sqrt[(s1^2/n1) + (s2^2/n2)], Where:

- mean1 is the mean loss of vegetable yield in the treatment with plastic packaging.
- mean2 is the mean loss of vegetable yield in the control without plastic packaging.
- s1 is the standard deviation of vegetable yield loss in the treatment with plastic packaging.
- s2 is the standard deviation of vegetable yield loss in the control without plastic packaging.
- n1 is the number of replications in the treatment with plastic packaging.
- n2 is the number of replications in the control without plastic packaging.

Based on the linear model above, an analysis of variance model can be constructed, as shown in the following table:

Source	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	F Ratio (F)	Critical F Value	
					5 %	1 %
Treatment	t - 1	$\sum Yi^2/ri - FK = (Y12r i + \cdots + Yt2rt) - FK$	JKP/ $t-1$			
Error	t(r–1)	JKT−JKP	KTG/ $t(r-1)$			
Total	tr - 1	$\sum i,j$Y2i,j--FK				

In this study, data analysis was conducted to determine the influence of each treatment using the F-test, as well as to identify differences between treatments using the Duncan multiple range test (Gazper, 1999). The data analysis was based on observations made regarding:

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1. Technical Efficiency Analysis Calculate the percentage of vegetable yield loss during storage for each treatment using the formula: Vegetable Yield Loss (%) = [(Initial Weight - Final Weight) / Initial Weight] x 100. Compare the percentage of vegetable yield loss between treatments using plastic packaging and the control (without plastic packaging).
2. Economic Efficiency Analysis Calculate the total cost of plastic packaging for each treatment. Sum up the cost of plastic packaging for each replication within the treatment. Compare the total costs between treatments using plastic packaging and the control using the following formula: Economic Value Efficiency = Selling Price of Vegetables - (Purchase Price of Vegetables - Operational Costs). Compare the economic value of vegetable yield loss between treatments using plastic packaging and the control (without plastic packaging).

RESULTS AND DISCUSSION

Technical Efficiency Analysis

The analysis of technical efficiency involves measuring the weight of vegetables at the end of the study compared to the initial weight (Appendix 1), indicating differences between treatments with and without plastic packaging. Statistical analysis of vegetables using plastic packaging compared to those without plastic packaging shows a significant difference (Table 1).

Table 1. Analysis of Variance (ANOVA) on the Effect of Plastic Packaging Usage on Vegetable Weight Loss

Source of Variation	DF	SS	MS	F-Value	F 0.05	F 0.01
Treatment	5	16,865.97	3,373.19	1,167.225**	2.45	3.514
Error	33	95.37	2.89			
Total	38	16,961.34				

Note: **= Very significant difference

Appendix 2 involves measuring the percentage of vegetable yield loss during storage compared to the initial weight. Statistical analysis of yield loss across treatments with plastic packaging shows a significant difference compared to vegetables without plastic packaging (control), as presented in Table 2.

Table 2. Effect of Plastic Packaging on Vegetable Yield Loss

	Treatment	Average Yield Loss (%)	
A	Cabbage with plastic packaging	0,403	a
B	Carrot with plastic packaging	1,352	a
C	Green beans with plastic packaging	1,826	a
E	Carrot without plastic packaging	49,862	b
F	Green beans without plastic packaging	50,575	b
D	Cabbage without plastic packaging	51,159	b

Note: Average values with the same letter are not significantly different according to Duncan's test at a significance level of 0.05.

From Table 2, it's evident that treatments A, B, and C show significantly lower yield loss compared to treatments D, E, and F (without plastic packaging). This demonstrates that the use of plastic packaging can reduce yield loss effectively. These findings align with Waryat & Handayani (2020) statement that weight loss is a crucial indicator of agricultural product quality decline. Changes in weight loss are monitored to understand

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the variation in vegetable weight loss during storage. The reduction in weight loss occurs initially across all packaging treatments but decreases more rapidly in the control group (unwrapped). Vegetable weight loss during storage is attributed to moisture loss, influenced by physiological processes such as evaporation, respiration, and other reaction processes. Since leafy vegetables contain 80-90% water, some moisture may be lost through these physiological processes. In high humidity, evaporation occurs more rapidly than at low temperatures.

According to Elik et al. (2019), post-harvest losses pose challenges to global food security and hunger in many countries. Fruit and vegetable losses reach 50%, making the reduction of fruit and vegetable losses and waste one of the main issues in providing sustainable food for the world's population in the future. The primary causes of post-harvest losses in fruits and vegetables are harvesting, handling, post-harvest storage, processing, distribution, and consumption. Therefore, proper post-harvest handling, packaging, transportation, and storage are crucial to minimize post-harvest weight loss.

Moreover, Ahlawat & Liu (2021) emphasize that the post-harvest shelf life of perishable products remains a challenge in the global fresh produce market supply chain. Post-harvest shelf life is determined by maturity level and storage conditions, affected by harvest time and storage conditions. Ripening and senescence are largely regulated by ethylene, inducing many metabolic effects on harvested products and causing physiological changes and developments during the post-harvest period. The traditional supply chain for most perishable products is long and complex, with post-harvest losses ranging from 12% to 46% after seven days of storage. Therefore, improving post-harvest quality sustainability is crucial to avoid losses and increase crop value. Numerous studies have investigated physiological and biochemical changes in fruits and vegetables during post-harvest aging.

Economic Efficiency Analysis

The analysis of economic efficiency involves calculating the economic value of vegetables at the end of the study compared to the initial value (Appendix 3), indicating differences between treatments with and without plastic packaging. Statistical analysis of the economic value of yield loss from treatments with plastic packaging shows a significant difference compared to vegetables without plastic packaging (control). The results of the statistical analysis of plastic packaging usage are presented in Table 3.

Table 3. Analysis of Variance (ANOVA) on the Effect of Plastic Packaging Usage on the Economic Value of Vegetables

Source of Variation	DF	SS	MS	F-Value	F 0.05	F 0.01
Treatment	5	136,852,992	27,370,598.32	22,202.089**	2.45	3.514
Error	33	40,682	1,232.79			
Total	38	136,893,674				

Note: **= Very significant difference

Appendix 3 involves measuring the economic value of vegetables during storage compared to the initial value. Statistical analysis of the economic value across treatments with plastic packaging shows a significant difference compared to vegetables without plastic packaging (control), as presented in Table 4.

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Table 4. Effect of Plastic Packaging on the Economic Value of Vegetables

	Treatment	Average Economic Value (Rp)
A	Cabbage with plastic packaging	4.980 a
B	Carrot with plastic packaging	4.932 a
C	Green beans with plastic packaging	4.909 a
E	Carrot without plastic packaging	501 b
F	Green beans without plastic packaging	494 b
D	Cabbage without plastic packaging	488 b

Note: Average values with the same letter are not significantly different according to Duncan's test at a significance level of 0.05.

From Table 4, it can be observed that treatments A, B, and C show a significant difference in lower economic value compared to treatments D, E, and F, which experience a significant decrease in economic value. These findings demonstrate that weight loss can decrease the economic value of vegetables. This aligns with Gomez et al. (2023) statement that weight loss is a crucial indicator of agricultural product quality decline. The value of product shrinkage is determined by recording the cumulative percentage of weight loss from the initial fruit weight during storage and the known weight loss on observation days in ambient and cold conditions. The "climate" of banana fruits is understood as the peak of sweating from various treatments and the loss of firmness when the fruit touches the shelf. The value is expressed as the number of days the fruit can maintain its marketability. Fruits obtained from these treatments are considered unsuitable for sale due to their softness and reduced ripeness. The rate of banana fruit respiration at the initial stage and during storage.

According to Khalid et al. (2023), food waste also results in significant financial losses. Food waste increases, and high-income households lose money. Similarly, there is a positive correlation between household income and the value of discarded food. This is one of the few studies on household food waste made by households in developing countries with both low and high incomes. Income levels in urban areas indicate that more food is wasted regardless of household type. This suggests that high-income individuals waste more food than low-income individuals. Financial performance can be improved by reducing food waste, freeing up resources for health, education, and welfare. Behavior and perspectives on food waste are crucial. People store food for later consumption but fail to do so, which is a significant factor contributing to food waste.

These results are related to the ability of plastic to reduce transpiration in vegetables, thereby preventing excessive vegetable mass/weight reduction. From this perspective, it can be stated that the use of plastic packaging has a positive effect on the economic value of packaged vegetables due to the reduction in vegetable weight loss. Therefore, if the average prices of each vegetable are calculated as shown in Table 5.

Table 5. Effect of Plastic Packaging on the Economic Value of Commodities

No	Commodity	Treatment	Initial Price (Rp)	Final Price (Rp)
1	Cabbage	Plastic packaging	5,000,-	4,980,-
2	Carrot	Plastic packaging	5,000,-	4,932,-

No	Commodity	Treatment	Initial Price (Rp)	Final Price (Rp)
3	Green beans	Plastic packaging	5,000,-	4,909,-
4	Carrot	Without plastic packaging	5,000,-	501,-
5	Green beans	Without plastic packaging	5,000,-	494,-
6	Cabbage	Without plastic packaging	5,000,-	488,-

Note: Economically, there is a significant decrease in value in treatments without plastic packaging.

From Table 5, it can be explained that, from the conversion of vegetable yield loss and quality aspects to economic value, the treatments with plastic packaging for each commodity are as follows: cabbage decreased from the initial price of Rp. 5,000,- to Rp. 4,980,- (a decrease of 0.40%), carrot decreased from the initial price of Rp. 5,000,- to Rp. 4,932,- (a decrease of 1.36%), and green beans decreased from the initial price of Rp. 5,000,- to Rp. 4,909,- (a decrease of 1.82%). Meanwhile, treatments without plastic packaging for each commodity are as follows: carrot decreased from the initial price of Rp. 5,000,- to Rp. 501,- (a decrease of 89.98%), green beans decreased from the initial price of Rp. 5,000,- to Rp. 494,- (a decrease of 90.12%), and cabbage decreased from the initial price of Rp. 5,000,- to Rp. 488,- (a decrease of 90.24%).

CONCLUSIONS

Based on the findings presented, it can be concluded that the use of plastic packaging for vegetables is highly beneficial, as it can significantly enhance the vegetables' shelf life, thus reducing yield losses. According to the Vegetable Yield Loss calculation, the results indicate that the use of plastic packaging for each commodity resulted in: 0.403% for cabbage, 1.352% for carrots, and 1.826% for green beans. In contrast, without plastic packaging, the yield losses for each commodity were significantly higher: 51.159% for cabbage, 49.862% for carrots, and 50.575% for green beans. Therefore, the utilization of plastic packaging substantially improves the vegetable storage process by minimizing yield losses compared to packaging-free methods, thus demonstrating higher technical efficiency. Additionally, plastic packaging maintains the economic value of the vegetables. Further calculations reveal that the cost of treatment with plastic packaging for each commodity amounted to: Rp. 4980 for cabbage, Rp. 4932 for carrots, and Rp. 4909 for green beans. Conversely, treatment without plastic packaging incurred significantly lower costs: Rp. 488 for cabbage, Rp. 501 for carrots, and Rp. 494 for green beans. Hence, economically, the use of plastic packaging proves to be more efficient.

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