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Analysis of Storage and Packaging Conditions on Physicochemical Characteristics of Eggplant (*Solanum melongena* L.)

Analisis Kondisi Penyimpanan dan Pengemasan pada Karakteristik Fisikokimia Terung (Solanum melongena L.*)*

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Abstract

Eggplant (*Solanum melongena* L.) is a horticultural product widely distributed in Indonesia and is an easily damaged commodity during storage. Suitable storage conditions are needed to increase the eggplant's shelf-life. This study aims to determine the differences and the best conditions of packaging type, storage temperature, and shelf-life to maintain and improve the eggplant's quality. This research was conducted using a Nested Design with three replications. The analysis used includes weight loss, moisture content, ash content, pH, firmness level, protein content, fat content, and carbohydrates content. The results indicate that storage at cold temperatures (±8 °C) can inhibit metabolic processes, so there is a decrease in protein and carbohydrate content due to lower respiration processes than eggplant stored at room temperature (±27 °C). The type of polyethylene (PE) plastic packaging can reduce the potential for damage to eggplant during storage and increase the eggplant's shelf-life compared to brown kraft paper bag packaging and without packaging, which is characterized by better weight loss, protein, carbohydrates, and texture. Storage treatment for five days at cold temperatures (±8 °C) with PE plastic packaging was the best treatment in this study.
Keywords: eggplant, packaging, storage, temperature

Abstrak

Terung (Solanum melongena L.) merupakan produk tanaman hortikultura yang sudah banyak tersebar di Indonesia dan merupakan komoditas yang mudah mengalami kerusakan selama penyimpanan. Kondisi penyimpanan yang sesuai dibutuhkan untuk meningkatkan umur simpan terung. Penelitian ini bertujuan mengetahui perbedaan dan kondisi terbaik penggunaan jenis kemasan, suhu penyimpanan, dan umur penyimpanan untuk mempertahankan dan meningkatkan kualitas terung. Penelitian ini dilakukan menggunakan Rancangan Nested dengan tiga kali ulangan. Analisa yang digunakan dalam penelitian ini meliputi analisa susut bobot, kadar air, kadar abu, pH, kekerasan, protein, lemak, dan karbohidrat. Hasil dari penelitian ini menunjukkan bahwa penyimpanan pada suhu dingin (±8 °C) dapat menghambat proses metabolisme sehingga terjadi penurunan kandungan protein dan karbohidrat yang disebabkan proses respirasi lebih rendah dibandingkan terung yang disimpan pada suhu ruang (±27 °C). Jenis kemasan plastik polyethylene (PE) mampu menurunkan potensi kerusakan terung selama penyimpanan dan meningkatkan umur simpan terung dibandingkan kemasan kraft paper bag *cokelat dan tanpa kemasan yang ditandai hasil susut bobot, protein, karbohidrat, dan tekstur yang lebih baik. Perlakuan penyimpanan lima hari pada suhu dingin (±8 °C) dengan kemasan plastik PE merupakan perlakuan terbaik pada penelitian ini.*
Kata kunci: *pengemasan, penyimpanan, suhu, terung*

INTRODUCTION

Eggplant (*Solanum melongena* L.) is one of Indonesia's widely distributed horticultural products. The eggplant plant comes from Sri Lanka and India. Eggplant is very popular with the public because the fruit has a variety of colors; purple, green, and white (Marviana & Utami, 2014). The demand for eggplant is increasing along with the increase in population. The production increase did not match the demand increase. This condition could be due to the low productivity of eggplant farmers. According to Statistics Indonesia, eggplant production in

Indonesia reached 575,392 tons in 2020 (Badan Pusat Statistik, 2020).

Data of eggplant plantations in Banyuwangi Regency showed that the land area (Ha) from year to year shows a significant decrease. The land area in 2013 was 238 Ha and then decreased to 124 Ha in 2014. According to the Banyuwangi Regency Central Statistics Agency, 2015-2018 showed an increase in land area but not significant, between 147 - 158 Ha. The decline in the land area again occurred in 2019, which was 123 Ha (Badan Pusat Statistik Kabupaten Banyuwangi, 2019).

The problem of eggplant post-harvest handling, in general, is that the harvest is done earlier so that the eggplant has a small size resulting in small yields per unit area. In contrast, the delayed harvest causes a hard eggplant texture, so consumers less like it. Postharvest is closely related to marketing objectives, which farmers have not carried out optimally. Research on this type of packaging used is one of the studies that aim to increase the shelf-life of eggplant so that the quality and quantity of eggplant products do not decrease when stored for a long time. The combination of storage temperature and storage time is one of the essential parameters in maintaining horticultural product quality, including eggplant. This study aims to determine the differences and the best conditions for using packaging type, storage temperature, and shelf-life to maintain and improve the quality of eggplant.

METHODS

The treatment used in this study are shelf-life, storage temperature, and packaging type. Eggplants are obtained directly from farmers' gardens in the Rogojampi area, Banyuwangi. The criteria of eggplant are harvested in the morning with fresh condition, around three months old, purple skin, and with no hard flesh. Eggplant with homogeneous conditions was selected according to the number of treatments and replications. Eggplants were analyzed for initial pH, firmness, water, ash, protein, fat, and carbohydrate content.

The tools and apparatus used in this study include a desk shelf, refrigerator, analytical scale (Denver-Instrument M-310), hand penetrometer fruit (Lutron, FR-5120, Taiwan) 3 mm diameter, digital thermometer, scissors, food-grade knife, plastic tape, beaker glass, plastic wrap, Kjeldahl tube, pH meter, digital oven (Local, Indonesia), furnace, desiccator (Nucerite), fume hood, volumetric flask, measuring cylinder, and electric stove. The main ingredients used in this research include eggplant (*Solanum melongena* L.), brown kraft paper bag, cardboard backing, PE plastic, distilled water, and reagents for protein and fat content analysis.

Research design

The research design was selected using a Nested experimental design with three factors; shelf-life (5 days, 10 days, and 15 days); storage temperature (room temperature ±27 °C and cold temperature ±8 °C); type of packaging (without packaging, PE plastic, and brown kraft paper bag). Repetition was carried out three times for each analysis so that 54 experimental units were obtained. The best treatment was determined using the Multiple Attribute method (Susilo et al., 2016).

Weight Loss Measurement

The sample's initial weight was weighed before the eggplant was stored. Subsequent observations were made by weighing the samples before and after storage on an n-th day. The eggplant weight loss was analyzed by the percentage change in eggplant weight. The percentage of eggplant weight loss was calculated based on the following equation (Paath et al., 2017):

$$W = ((A-B)/A) \times 100\% \quad (1)$$

where,

W: Weight loss
A: Eggplant initial weight
B: Eggplant weight at n-th day

Water Content Measurement

Eggplant samples were mashed using a mortar. 2 grams of finely mashed samples were placed into a petri dish whose constant weight is known. The sample and petri dish weight was measured. The sample was then dried in an oven at 105 °C for 5 hours. The sample was cooled in a desiccator and weighed again. The sample was dried again for 2 hours until the weight was constant (the minimum difference in scale was 0.2 mg, respectively). The weight lost is assumed to be the sample water weight. The water content was calculated based on the following equation (AOAC, 2011):

$$\text{Moisture content (\%)} = ((\text{Initial weight-final weight})/(\text{initial weight})) \times 100\% \quad (2)$$

Ash Content Measurement

Eggplant samples were crushed using a mortar and weighed 2 grams. The eggplant sample was placed on an oven-dried porcelain dish at 105 °C for 5 hours. The sample was heated on an electric stove in a fume hood until it was smokeless for 1-2 hours. Ashing is carried out in a muffle furnace at 600 °C for 5 hours or until white ash is formed in the cup. The muffle furnace was turned off, and the sample was left in the apparatus for 1 hour until it was warm. The sample was put in an oven at 105 °C. The cup is removed and cooled in a desiccator until a constant weight is reached. Calculation of ash content using the following equation (AOAC, 1990):

$$\text{Ash content (\%)} = ((\text{ash weight})/(\text{sample weight})) \times 100\% \quad (3)$$

pH Measurement

The eggplant was crushed using a mortar until smooth, and 1 gram was taken and placed in a 50 ml glass beaker. Distilled water with pH 6.8 30 ml was added until homogeneous, and a flurry was formed. Calibration was carried out on a pH meter with buffers of pH 4 and 7. Then the pH meter was cleaned with distilled water and dried with a tissue. The pH meter tip was then dipped into the flurry sample, measured for about 10 minutes, and recorded. For other sample measurements, the pH meter was first cleaned with distilled water and dried again with a tissue (Karangan et al., 2019).

Firmness Measurement

The texture of eggplant samples was measured using a hand penetrometer fruit (Lutron, FR-5120, Taiwan) with a diameter of 3 mm (Naibaho et al., 2013). The eggplant sample was taken 20 grams, placed under the hand penetrometer fruit, and adjusted so that the measuring device touched the sample. The eggplant sample is pressed until a signal is heard. Measurements were done in three parts; the eggplant's top, middle, and bottom. The numbers listed on the hand penetrometer fruit are read and recorded. Fruit firmness was measured by hand penetrometer fruit using the equation (Naibaho et al., 2013):

$$\text{Firmness level (N/mm}^2) = \text{applied force (N)} / \text{surface area (mm}^2) \quad (4)$$

The firmness value is obtained from the average calculation of the firmness value in 3 different parts of the eggplant sample. The firmness value obtained describes the texture of the whole eggplant sample.

Protein Content Measurement

Protein measurements were carried out following the modified Association of Official Agricultural Chemists (AOAC, 1990) method. The eggplant sample was crushed with a mortar and weighed 1 gram (1 ml of distilled water for blanks) in a Kjeldahl flask. Kjeldahl tablets of 0.5 grams and 15 ml of concentrated H2SO4 were added to the Kjeldahl flask and then destructed in a fume hood at 200-250 °C for 1 hour. The fume hood was turned off, and waited for the Kjeldahl flask to cool. The sample from the destruction is put into an Erlenmeyer. 10 ml of distilled water and two drops of phenolphthalein indicator were added to an Erlenmeyer containing the destructed sample. The distillate was accommodated into an Erlenmeyer filled with 20 ml of 3% boric acid and three drops of methyl red. Distillation was carried out for 3 minutes using a distiller. The distillate was titrated with 0.1 N HCl until the color changed from clear yellow to pink. Protein content can be calculated using the following equation:

$$\%\ \text{N} = \frac{(\text{ml HCl sample} - \text{ml HCl blank}) \times \text{N HCl} \times 14.008}{\text{sample weight} \times 1000} \quad (5)$$

$$\text{Protein content (\%)} = \%\ \text{N} \times \text{conversion factor (6.25)} \quad (6)$$

Fat Content Measurement

The fat content sample measurement was performed using the modified method from Pargiyanti (2019). The eggplant sample was mashed and weighed 1 gram. Soxhlet flask and samples were dried in the oven for approximately 1 hour. The sample is wrapped in filter paper. The initial weight of the Soxhlet flask was weighed and then filled with 35 ml of petroleum ether. Soxhlet distillation apparatus was assembled and extracted for 5 hours. Soxhlet flask containing fat and oil extract was dried in an oven at 105 °C for 1 hour. The final weight of the Soxhlet flask was weighed to a constant. Fat content can be calculated using the equation:

$$\text{Fat content (\%)} = \frac{(\text{soxhlet flask final weight} - \text{soxhlet flask initial weight})}{\text{sample weight}} \times 100\% \quad (7)$$

Carbohydrate Content Measurement

Carbohydrate content is determined using the difference method (Budiarti et al., 2016); the calculation involves water, ash, protein, and fat content. The equation used in calculating carbohydrate content using the by difference method is as follows:

Carbohydrate content (%) = 100% - (% water content + % ash content + % protein content + % fat content) (8)

Data Analysis

The study was conducted with a Nested Design using a combination of 3 factors, shelf-life (5, 10, and 15 days), storage temperature (room temperature ±27 °C and cold temperature ±8 °C), and packaging (without packaging, PE plastic, and brown kraft paper bags). The data obtained were analyzed using Analysis of Variance (ANOVA) using Excel 2010 and Minitab17 with a 95% confidence interval. The results of the ANOVA test showed a significant effect of the treatment factors tested.

Further tests were performed using the Tukey method with a 95% confidence interval using Minitab17. Tukey's advanced test, often called the honestly significant difference (HSD), is a method used to compare the mean in pairs based on the range distribution, which aims to see the difference in the values in each sample (Wulandari et al., 2017). The best treatment was selected using the Multiple Attribute method (Susilo et al., 2016). The best treatment ranking determination is based on the L1, L2, and Lmax sum results. The lower the sum, the higher the treatment ranking. The best treatment determination with the Multiple Attribute method is as follows:

1. The ideal value is determined for each parameter by calculating the degree of density (dk i).
   If the ideal value (dk i) is minimal, then:

$$\text{dk i} = \frac{\text{Actual values that are close to ideal}}{\text{The ideal value of each alternative}} \quad (9)$$

If the ideal value (dk i) is maximum, then:

$$\text{dk i} = \frac{\text{The ideal value of each alternative}}{\text{Actual values that are close to idea}} \quad (10)$$

2. The density distance (Lp) is calculated assuming all essential parameters, calculated based on the number of parameters:

$$\lambda = 1/\Sigma \text{ parameter} \quad (11)$$
$$L1 = 1-\Sigma (\lambda^{2}*(1-dk)) \quad (12)$$
$$L2 = \Sigma (\lambda^{2}*(1-dk)^{2}) \quad (13)$$
$$Lmax = \max \lambda i\ (1 - dk\ i). \quad (14)$$

The best treatment was chosen from the treatment with the lowest L1, L2, and Lmax values.

RESULTS AND DISCUSSION

Eggplant Characteristics

The raw material for fresh eggplant used in this study was analyzed first. The characteristics of the raw material analysis are presented in Table 1. The characteristics analysis of eggplant includes water content, ash content, protein content, fat content, carbohydrate content, pH, and firmness.

The analysis results showed that eggplant contains 86.04% water content, 0.57% ash content, 1.86% protein content, 0.34% fat content, 11.19% carbohydrate content, pH 4.77, and the eggplant firmness is 224.38 N/mm^2. Fresh eggplant is a commodity that contains a lot of water and carbohydrates. The analysis results were compared with the analysis results by Rodriguez-Jimenez et al. (2018). Some of the differences can be caused by several factors such as eggplant varieties used, growing conditions, and the analysis conditions.

Table 1. Fresh eggplant characteristics

Parameters	Fresh Eggplant	Literature Results	Literature Source
Water Content (%)	86.04 ±0.52	90%	
Ash Content (%)	0.57 ±0.01	0.55%	
Protein Content (%)	1.86 ±0.05	1.07%	(Rodriguez-Jimenez et al., 2018)
Fat Content (%)	0.34 ±0.03	0.15%	
Carbohydrate Content (%)	11.19 ±0.52	5.69%	
pH	4.77 ±0.09	-	
Firmness (N/mm^2)	224.38 ±1.37	-	

Data (± standard deviation) is the mean of 3 replications.

Eggplant Post-Harvest Changes during Storage

Table 2 shows the analysis results of eggplant weight loss, water content, and ash content in each treatment.

Eggplant Weight Loss

Eggplant Weight loss due to post-harvest treatment, including shelf-life, storage temperature, and storage packaging, ranged from 0.62 to 33.43%. ANOVA test showed that the shelf-life, storage temperature, and packaging had a significant effect (α = 0.05) on the eggplant weight loss. Eggplant weight loss will increase with the long shelf-life. The highest weight loss occurred on the 15th day of shelf-life. Eggplant catabolism breaks down macronutrient components into micronutrients as an energy source. This energy will be used for respiration which produces CO_2 and water. The product respiration rate is an indicator of tissue metabolic activity. This statement can be used as a product shelf-life vital indicator (Sudjatha & Wisaniyasa, 2017).

Eggplant weight loss stored at room temperature tends to be higher than cold storage. This result is due to several factors, including the water vapor equilibrium in the air under different (cold) room and refrigerator conditions. Murtiwulandari et al. (2020) stated that storage at low temperatures effectively extends the shelf-life of fresh ingredients because it can reduce respiration activity, the aging process, enzyme activity, and microorganisms' growth.

Packaging significantly affects eggplant weight loss stored in this study. PE plastic packaging can inhibit weight loss with the lowest shrinkage value compared to unpackaged and brown kraft paper bag packaging. PE plastic packaging has a low permeability to water vapor. High humidity in the packaging can keep water out of the product surface. The material's low permeability can press the water out to the environment so that weight loss due to evaporation can be suppressed (Lamona et al., 2015).

Eggplant Water Content

Due to shelf-life, temperature, and packaging treatment, the eggplant water content ranged from 87.56 to 92.99%. ANOVA test showed that shelf-life, temperature, and packaging significantly affected the eggplant water content. The eggplant water content increased with long shelf-life. The highest eggplant water content was found on the 15th day, followed by the 10th and 5th days. The analysis also showed that the storage temperature affected the eggplant water content during storage. Room temperature (±27 °C) produces eggplant with a higher water content than the cold

Table 2. Eggplant weight loss (%), water content (%), and ash content (%)

Shelf-life	Storage Temperature	Packaging	Weight Loss (%)	Water Content (%)	Ash Content (%)
5 days	Room temperature (±27 °C)	Unpackaged	20.66 ±1.97^{ef}	90.64 ±0.52^{abcd}	0.64 ±0.03^{def}
		PE plastic	3.01 ±1.97^{hi}	89.23 ±0.48^{bcde}	0.51 ±0.02^{h}
		Brown Kraft Paper Bag	19.33 ±0.95^{ef}	90.07 ±0.36^{bcde}	0.57 ±0.02^{fgh}
	Cold temperature (±8 °C)	Unpackaged	11.24 ±0.95^{g}	89.38 ±0.42^{bcde}	0.66 ±0.03^{de}
		PE plastic	0.62 ±0.06^{i}	87.56 ±0.60^{e}	0.54 ±0.03^{gh}
		Brown Kraft Paper Bag	10.97 ±0.39^{g}	88.87 ±0.38^{cde}	0.64 ±0.01^{def}
10 days	Room temperature (±27 °C)	Unpackaged	28.45 ±2.05^{bc}	91.66 ±0.53^{ab}	0.71 ±0.02^{bcd}
		PE plastic	5.29 ±0.47^{h}	90.05 ±0.25^{bcde}	0.56 ±0.02^{fgh}
		Brown Kraft Paper Bag	29.81 ±2.40^{ab}	90.66 ±0.20^{abcd}	0.60 ±0.02^{efg}
	Cold temperature (±8 °C)	Unpackaged	19.26 ±1.15^{ef}	90.20 ±0.24^{bcde}	0.77 ±0.01^{ab}
		PE plastic	4.07 ±0.11^{hi}	88.42 ±0.37^{de}	0.57 ±0.02^{fgh}
		Brown Kraft Paper Bag	17.83 ±1.63^{f}	89.26 ±0.16^{bcde}	0.69 ±0.02^{cde}
15 days	Room temperature (±27 °C)	Unpackaged	33.43 ±2.35^{a}	92.99 ±0.30^{a}	0.81 ±0.02^{a}
		PE plastic	6.30 ±0.29^{h}	91.15 ±0.31^{abc}	0.68 ±0.03^{cde}
		Brown Kraft Paper Bag	32.86 ±0.68^{a}	91.87 ±0.14^{ab}	0.72 ±0.02^{bcd}
	Cold temperature (±8 °C)	Unpackaged	25.67 ±1.29^{cd}	90.97 ±3.22^{abcd}	0.84 ±0.08^{a}
		PE plastic	5.26 ±0.38^{h}	88.58 ±0.94^{cde}	0.68 ±0.01^{cde}
		Brown Kraft Paper Bag	22.15 ±1.59^{de}	90.09 ±0.13^{bcde}	0.76 ±0.02^{abc}

Data (± standard deviation) is the mean of 3 replications.
Different letters besides numbers indicate significant differences in each treatment (α = 0.05).

temperature (±8 °C). The increase in eggplant respiration at room temperature also increases water vapor. The respiration process of eggplant stored at low temperatures is more inhibited, which causes water production to be lower than room temperature. Storage at low temperatures effectively preserves fresh vegetable and fruit products, reduces the risk of the browning reaction, and prevents commodity spoilage (Massolo et al., 2011).

Eggplant stored unpackaged had the highest water content, then eggplant packaged in brown kraft paper bag and PE plastic. The packaging can prevent direct contact between the sample and the environment around the storage area. Samples without packaging are more easily exposed to air directly, resulting in accelerated eggplant catabolism. PE plastic packaging inhibits respiration, so the water content does not increase excessively. PE plastic has a low permeability to withstand the water vapor produced and withstand outside interactions with the material, causing a decreased transpiration rate (Waryat & Handayani, 2020).

Eggplant Ash Content

Due to post-harvest treatment, which includes shelf-life, temperature, and storage packaging, the eggplant ash content ranges from 0.51 to 0.81%. ANOVA test showed that shelf-life, temperature, and packaging significantly affected the eggplant ash content. The 15th day of storage had a higher ash content, followed by the 10th and 5th days of storage. The eggplant weight loss percentage was higher if the storage was longer. This condition causes the ash content to increase as an inorganic substance that does not evaporate during combustion with other organic substances. Eggplant stored at cold temperatures had a higher ash content than room temperature. The amount of ash content mineral elements as inorganic substances is very dependent on the commodity during plant growth in the field. Organic materials will burn in the ashing process, while inorganic materials not. The ash content and composition are strongly influenced by material type and ashing conditions. Ash composition describes mineral content and is strongly influenced by soil conditions, fertilization, and irrigation while plants grow in the field (Zhao et al., 2009).

Eggplant stored unpackage produced the highest ash content, then eggplant packaged in brown kraft paper bags and PE plastic. This result is because the unpackaged eggplant has lost a lot of weight loss during storage, so the percentage of organic compounds (including water) in the eggplant decreases. PE plastic can withstand water evaporation, reducing eggplant weight loss. This condition significantly affects the composition of inorganic components in eggplant. Eggplant from PE plastic packaging has a lower ash content because it still contains many organic components. Arianto et al. (2013) stated that plastic packaging could effectively inhibit the decrease in water content, which affects the composition of ash content as an inorganic component.

Eggplant Firmness

Due to post-harvest treatment, including shelf-life, temperature, and storage packaging, the eggplant firmness ranged from 162.22 to 221.27 N/mm^2 (Table 3). ANOVA test showed that the shelf-life and storage temperature significantly affect ($\alpha = 0.05$) the eggplant firmness. However, the packaging type did not significantly affect the eggplant firmness. After five days of storage, the eggplant firmness level on PE plastic reached 193.54 ±11.55 N/mm^2 at room temperature and 221.27 ±5.59 N/mm^2 at cold temperature. The eggplant firmness level in PE plastic packaging was 184.32 ±5.10 N/mm^2 at ten days of storage at room temperature and 211.54 ±5.59 N/mm^2 at cold temperature. The eggplant firmness level with PE plastic packaging was 171.93 ±10.54 N/mm^2 at 15 days of storage at room temperature and 210.54 ±10.08 N/mm^2 at cold temperature. The PE plastic packaging was chosen because it is flexible, elastic, waterproof, and readily available. It is very suitable for daily needs eggplant packaging.

The longer the storage, the eggplant firmness is also lower. The firmness value decrease indicated eggplant's softer texture. Changes in pectin content by enzyme activity occur during the fruit ripening process. This condition causes the eggplant to become soft. The same results were also obtained from Andriani et al. (2018) research on tomato commodities. If the storage is extended, then texture degradation occurs, which causes the texture of the new commodity to be softer.

Eggplant pH

Due to post-harvest treatment, including shelf-life, temperature, and storage packaging, the

Table 3. Eggplant firmness (N/mm^2) and pH

Shelf-life	Storage Temperature	Packaging	Firmness (N/mm^2)	pH
5 days	Room temperature (±27 °C)	Unpackaged	183.59 ±5.75 ^{cdefg}	5.94 ±0.08^{abcd}
		PE plastic	193.54 ±11.55^{bcde}	5.36 ±0.05^{h}
		Brown Kraft Paper Bag	187.91 ±2.46^{bcdef}	5.50 ±0.02^{fgh}
	Cold temperature (±8 °C)	Unpackaged	205.35 ±5.28^{abc}	5.56 ±0.06^{defgh}
		PE plastic	221.27 ±1.18^{a}	5.54 ±0.12^{efgh}
		Brown Kraft Paper Bag	212.26 ±10.42^{ab}	5.47 ±0.35^{gh}
10 days	Room temperature (±27 °C)	Unpackaged	177.93 ±6.92^{defg}	6.02 ±0.02^{ab}
		PE plastic	184.32 ±5.10^{cdefg}	5.70 ±0.01^{bcdefgh}
		Brown Kraft Paper Bag	179.83 ±3.55 ^{defg}	5.88 ±0.01^{abcdef}
	Cold temperature (±8 °C)	Unpackaged	201.25 ±6.21^{abcd}	5.60 ±0.25^{cdefgh}
		PE plastic	211.54 ±5.59^{ab}	5.58 ±0.17 ^{defgh}
		Brown Kraft Paper Bag	207.70 ±12.98^{abc}	5.59 ±0.01 ^{defgh}
15 days	Room temperature (±27 °C)	Unpackaged	162.22 ±7.25^{g}	6.09 ±0.02^{a}
		PE plastic	171.93 ±10.54^{efg}	5.91 ±0.02^{abcde}
		Brown Kraft Paper Bag	163.18 ±14.78^{fg}	5.98 ±0.02^{abc}
	Cold temperature (±8 °C)	Unpackaged	198.79 ±2.41^{abcd}	5.80 ±0.03^{abcdefg}
		PE plastic	210.54 ±10.08^{ab}	5.74 ±0.22^{abcdefgh}
		Brown Kraft Paper Bag	205.22 ±8.71^{abc}	5.78 ±0.01^{abcdefg}

Data (± standard deviation) is the mean of 3 replications.
Different letters besides numbers indicate significant differences in each treatment (α = 0.05).

eggplant pH ranged from 5.36 to 6.09 (Table 3). ANOVA test showed that the shelf-life, storage temperature, and packaging type significantly affect (α = 0.05) the eggplant pH. Fluctuations in pH levels and temperature affect the pH levels decrease. The cold temperature (±8 °C) can lower the eggplant pH packaged in a brown kraft paper bag, PE plastic, or without packaging. The pH decrease maintained the eggplant physicochemical properties. Silaban et al. (2013) showed that eggplant, especially Dutch eggplant with a low pH level, produces a longer shelf-life than fruit with a higher pH content. Total acid amount changes of eggplant influence this condition. The low ascorbic acid content makes eggplant more durable in room temperature storage than fruit with high ascorbic acid content. Ascorbic acid is oxidized by air to form cupric ions involving hydrogen peroxide, namely the condensation of anthocyanins by ascorbic acid, which will damage the fruit quality and color (Sahid et al., 2014). PE plastic packaging has an excellent effect on maintaining the eggplant pH. Eggplant packaged in PE plastic at temperature treatment and shelf-life resulted in the lowest pH levels, 5.36 ±0.05 to 5.91 ±0.02.

Eggplant Protein Content

Due to post-harvest treatment, including shelf-life, temperature, and storage packaging, protein content in eggplant ranged from 1.54 to 1.82% (Table 4). The ANOVA test results showed that shelf-life, temperature, and packaging significantly affected protein content in eggplant. The lowest protein content occurred on the 15th day of storage, followed by the 10th and 5th days. The decrease in protein content was caused by the eggplant metabolic process, which was still ongoing during storage. The analysis results also showed that the eggplant protein content stored at room temperature was lower than at cold temperatures. This result is related to the metabolism intensity of eggplant, which is higher at room temperature than at cold temperatures. The PE plastic packaging can inhibit the decrease the eggplant protein levels. Eggplant stored unpackaged will have the highest decrease in protein content and the lowest total protein content, followed by eggplant from brown kraft paper bag packaging. A short shelf-life usually accompanies high respiration rates. This condition also indicates the quality decline rate and its value as a food ingredient (Arianto et al., 2013).

Eggplant Fat Content

Due to post-harvest treatment, including shelf-life, temperature, and storage packaging, the eggplant fat content ranged from 0.42 to 1.07% (Table 4). The ANOVA test results showed that the shelf-life, storage temperature, and type of

Table 4. Eggplant protein content (%), fat content (%), and carbohydrate content (%)

Shelf-life	Storage Temperature	Packaging	Protein Content (%)	Fat Content (%)	Carbohydrate Content (%)
5 days	Room temperature (±27 °C)	Unpackaged	1.74 ±0.02bcde	0.63 ±0.03hij	6.35 ±0.53efg
		PE plastic	1.82 ±0.03a	0.71 ±0.02fgh	7.73 ±0.44 bcd
		Brown Kraft Paper Bag	1.76 ±0.01abcd	0.90 ±0.02bc	6.70 ±0.37def
	Cold temperature (±8 °C)	Unpackaged	1.80 ±0.02abc	0.42 ±0.03m	7.74 ±0.38bcd
		PE plastic	1.81 ±0.01ab	0.45 ±0.03lm	9.64 ±0.61a
		Brown Kraft Paper Bag	1.72 ±0.04 cdef	0.76 ±0.01def	8.01 ±0.35bc
10 days	Room temperature (±27 °C)	Unpackaged	1.70 ±0.01 defgh	0.73 ±0.02efg	5.19 ±0.53gh
		PE plastic	1.76 ±0.04abcd	0.79 ±0.02 def	6.85 ±0.26 cdef
		Brown Kraft Paper Bag	1.68 ±0.02efghi	0.93 ±0.03b	6.12 ±0.24fgh
	Cold temperature (±8 °C)	Unpackaged	1.73 ±0.03cdef	0.52 ±0.02kl	6.78 ±0.22cdef
		PE plastic	1.76 ±0.01 abcd	0.54 ±0.04 jk	8.71 ±0.40ab
		Brown Kraft Paper Bag	1.66 ±0.04fghi	0.80 ±0.03de	7.60 ±0.18bcde
15 days	Room temperature (±27 °C)	Unpackaged	1.62 ±0.02ij	0.82 ±0.02cde	3.85 ±0.30i
		PE plastic	1.68 ±0.02 efghi	0.83 ±0.03cd	5.70 ±0.32 fgh
		Brown Kraft Paper Bag	1.54 ±0.03j	1.07 ±0.06a	4.94 ±0.19hi
	Cold temperature (±8 °C)	Unpackaged	1.65 ±0.02ghi	0.65 ±0.04ghi	5.37 ±0.47 gh
		PE plastic	1.71 ±0.03defg	0.61±0.04ijk	8.48 ±0.95ab
		Brown Kraft Paper Bag	1.63 ±0.04hi	0.82 ±0.02cde	6.72 ±0.15 cdef

Data (± standard deviation) is the mean of 3 replications.
Different letters besides numbers indicate significant differences in each treatment (α = 0.05).

packaging significantly affect (α = 0.05) the eggplant fat content. The eggplant fat content increased until the 15th day of storage. The eggplant on day 15 had the highest fat content, followed by days 10 and 5. This condition is because fat is the last nutrient reserve to be converted into energy. In using protein and fat as energy-producing substrates, the respiration quotient (RQ) value is less than 1. RQ is the ratio between the CO_2 produced and the O_2 used. The breakdown of protein and fat as energy substrates requires more O_2, which is needed to convert carbon into CO_2 and hydrogen into H_2O, so it takes more time to convert fat into energy. If glycerol trioleate is the substrate, then fat can be used as a raw material for respiration (Hartawan & Nengsih, 2012).

Eggplant stored at room temperature had a higher fat content than eggplant stored at cold temperature. This result is inversely proportional to the analysis results of protein and carbohydrate levels. Eggplant stored at room temperature will quickly decompose macro components (carbohydrates and protein) and leave fat as the last energy reserve. This condition causes the fat content in eggplant stored at room temperature to be higher than stored at cold temperature. The brown kraft paper bag packaging type produced eggplant with the highest fat content, followed by PE plastic packaging and without packaging. This condition can be due to the storage of unpackaged eggplant in direct contact with the air, which causes the eggplant to get much oxygen for respiration. Plastic as packaging is also a good material to protect products from interactions with the environment, increasing respiration and the decomposition of organic eggplant components (Arianto et al., 2013).

Eggplant Carbohydrate Content

Due to post-harvest treatment, including shelf-life, temperature, and storage packaging, the eggplant carbohydrate content ranged from 3.85 to 9.64% (Table 4). The ANOVA test result showed that the shelf-life, storage temperature, and packaging type significantly affect (α = 0.05) the eggplant carbohydrate content. The eggplant carbohydrate content decreased with increased shelf-life. On the 15th day of storage, eggplant had the lowest carbohydrate content, followed by the 10th and 5th days. Carbohydrates are macronutrient components used as the eggplant's primary energy source to be broken down into sugar and produce energy for respiration. The longer the shelf-life, the more respiration occurs so that the eggplant carbohydrate content also decreases. Eggplant at room temperature storage has lower carbohydrate content than eggplant at

Table 5. Parameter selection based on importance factor and best expectation value

Parameters	Expected Value
Weight Loss (%)	Lowest value
Water Content (%)	Lowest value
Ash Content (%)	Lowest value
Protein Content (%)	Lowest value
Fat Content (%)	Lowest value
Carbohydrate Content (%)	Lowest value
pH	Lowest value
Firmness (N/mm^2)	Lowest value

Table 6. Eggplant physicochemical characteristics of best treatment compared to fresh eggplant

Parameters	Expected Value	
	Eggplant with Best Storage Condition	Fresh Eggplant
Weight Loss (%)	0.62 ±0.06	-
Water Content (%)	87.56 ±0.60	86.04 ±0.52
Ash Content (%)	0.54 ±0.03	0.57 ±0.01
Protein Content (%)	1.81 ±0.01	1.86 ±0.05
Fat Content (%)	0.45 ±0.03	0.34 ±0.03
Carbohydrate Content (%)	9.64 ±0.61	11.19 ±0.52
pH	5.54 ±0.12	4.77 ±0.09
Firmness (N/mm^2)	221.27 ±1.18	224.38 ±1.37

Data (± standard deviation) is the mean of 3 replications.

cold temperature. Eggplants tend to do better respiration at room temperature than at cold temperatures. Widjanarko (2012) states that respiration reshuffles complex materials in cells (starch, sugar, and organic acids) with oxygen into simple molecules, such as CO_2, water, and energy.

The analysis results also showed that eggplant stored unpackaged had the lowest carbohydrate content compared to eggplant packaged in brown kraft paper bags and PE plastic. PE plastic can maintain eggplant carbohydrate levels so that the decrease is not excessive. This condition is related to the slowed respiration rate due to the minimum oxygen in PE plastic packaging. PE plastic packaging has low permeability, blocking the transfer of carbon dioxide, oxygen, and water vapor. Plastic packaging protects against water loss in vegetables so that packaged vegetables still look fresh (Rochman et al., 2007). Plastic as packaging is also an excellent material to protect products from interactions with the environment (Arianto et al., 2013). Brown kraft paper packaging has pores that allow respiration (Suryanto, 2013), affecting the eggplant carbohydrate content.

The Best Treatment Selection using Multiple Attribute Method

The Multiple Attributes method is used to select the best treatment for eggplant, considering the length of shelf-life, storage temperature, and storage packaging (Susilo et al., 2016). The best treatment parameters used in this study were eight parameters. Table 5 shows the best treatment selection based on the parameter of importance factor and the best expectations assessment. These parameters have an equally important weight.

Based on the best treatment calculation obtained, the best treatment eggplant storage conditions were eggplant packaged in PE plastic and stored for five days at a cold temperature. This result is supported by the calculation value results of the Multiple Attribute method. The physicochemical characteristics of eggplant packaged in PE plastic and stored for five days at a cold temperature compared to fresh eggplant as control are presented in Table 6.

CONCLUSIONS

Shelf-life, storage temperature, and packaging type significantly affect ($\alpha = 0.05$) the physicochemical characteristics of eggplants, such as weight loss (%), water content (%), ash content (%), protein content (%), fat content (%), carbohydrate content (%), and pH. Shelf-life and storage temperature also significantly affected the eggplant firmness (N/mm^2), while the packaging type did not. If the eggplant is stored prolonged, the weight loss, water content, ash content, fat content, and pH will increase, but the eggplant's protein, carbohydrate, and texture will decrease. Cold temperatures (±8 °C) can inhibit metabolism, such as eggplant respiration, which is characterized by protein and carbohydrates decreasing, lower than eggplant stored at room temperature (±27 °C). The PE plastic packaging type can reduce the potential eggplant damage during storage and increase eggplant shelf-life compared to brown kraft paper bag packaging and without packaging, shown by better weight loss, protein, carbohydrates, and firmness. The best treatment in this study was the storage of eggplant packaged in PE plastic and stored for five days at a cold temperature (±8 °C). Further research should perform organoleptic tests and handle finished products to increase shelf-life.

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