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Physical Quality of Fresh Cayenne Pepper (*Capsicum frutescens* L.) with Different Types of Packaging during Low Temperature Storage

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ABSTRACT

Cayenne pepper (Capsicum frutescens L.) is classified as a horticulture product that easly damaged and it can only survive for 2-3 days in room temperature conditions. In maintaining the quality and self life time of fresh cayenne pepper during storage it is recommended to use the packaging and storage at low temperature. The purpose of this study is to analize the effect of packaging type and storage length on the physical quality of fresh cayenne pepper during low temperature storage (5°C). This study used a complete randomized design method with two factors, each of which consisted of 3 levels, namely storage time (4, 8, and 12 days) and type of packaging (vacuum pack, perforated polypropyline plastic, and wrap plastic). The data were analized by using factorial Anova two mix factors test (α= 5%) and was followed up by Tukey test. The results showed that the best packaging was found in perforated polypropylene plastic with the lowest moisture content 76.45%, the lowest weight loss 3.87%, the highest texture (hardness) 0.027 N/mm², the highest lightness (L) 44.52, the lowest redness (a*) 26.7, the lowest yellowness (b*) 10.97, the lowest ΔE 23.47, and the lowest water activity 0.889. Physical quality of fresh cayenne pepper can last up to 12 days at low temperature storage (5°C) using perforated polypropylene plastic.*

1. INTRODUCTION

Cayenne pepper (*Capsicum frutescens* L.) is one of the vegetable commodities that people cannot leave behind in their daily lives. Based on data obtained from the Central Statistics Agency (BPS, 2020), the national production of cayenne pepper in Indonesia reached 1.51 million tons in 2020. This production increased by 9.76% compared to the previous year (2019) which amounted to 1.37 million tons. . Cayenne pepper is generally used as a flavoring dish, but cayenne pepper has other uses. Cayenne pepper is considered important to be used as raw material for ingredients in the food, beverage and drug industries. According to Nurdjannah *et al.* (2014), chili has the characteristics of being easily damaged, so it is very difficult to maintain the freshness of chili until the final consumer. The conventional handling of chili by farmers in Indonesia only has a very low shelf life of 2-3 days. Conditions of high temperature and humidity in tropical areas such as Indonesia greatly contribute to chili damage.

One way to keep chilies freshness for a long time is by storing them. Cold storage can extend shelf life and maintain chili quality and inhibit respiration (Santika, 2004). Storage using a temperature of 5 °C in chili shows optimal results in maintaining chili quality (Santika, 2004). The increase in the shelf life and quality of cayenne pepper during distribution and display in marketing (market display), cannot be separated from the packaging treatment applied. Proper packaging can reduce both the rate of transpiration and postharvest respiration rate of agricultural commodities. Packaging is an activity to protect the freshness of agricultural products during transportation, distribution and or storage so that product quality is maintained. The function of packaging is to protect the commodity from physical, mechanical and microbiological damage so as to create attractiveness for consumers and provide added value to the product and extend the shelf life of the product (Sembiring, 2009).

According to Winarno (2002), the use of plastic as a packaging material has advantages over other packaging materials due to its light, transparent, thermoplastic strength and selective permeability to water vapor, O_2, CO_2. The permeability properties of plastic can play a role in regulating the humidity of the storage space. The most common packaging for cayenne pepper is plastic. The plastics that are often used to package horticultural products are polyethylene, polypropylene, and low density polyethylene. Plastic packaging has several advantages, including low prices, easy to apply, able to withstand the rate of transpiration and postharvest respiration of agricultural products, light weight, transparent so that the packaged materials appear from the outside, and are easy to obtain (Anggraini, 2020).

The purpose of this study was to test the physical quality of fresh cayenne pepper in different types of packaging during low temperature storage (5 °C) and to analyze the effect of packaging type and storage time on the physical quality of fresh cayenne pepper during low temperature storage. In this study, the types of packaging used were vacuum plastic (vacuum pack), perforated polypropyline (PP) plastic and wrap plastic (clear polyethylene), then stored at a low temperature of 5 °C with different storage times, namely 4, 8, and 12 days. Some of the physical qualities of cayenne pepper studied were water content, weight loss, texture (level of hardness), color, and water activity. It is expected that with this method the physical quality of the storage of fresh cayenne pepper on different types of packaging and storage time can produce better physical quality.

2. MATERIALS AND METHODS

This research was conducted from January 2021 to March 2021 at the Agricultural Product Engineering Laboratory, Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Jember. The tools used in this research were digital scales ± 0.01 gram, Vacuum Sealer Kris VS200, refrigerator, penetrometer, Colorimeter CS-10, LabSwift water activity meters, oven, desiccator, aluminum sample cup, clamp, soldering iron, scissors, and a stopwatch. While the material used in this study was fresh white chili pepper obtained from cayenne pepper farmers in Sukowono Village, Sukowono District, Jember Regency, East Java. The packaging materials included vacuum plastic (vacuum pack) made of 80 mm polyethylene (PE), 80 mm polypropylene (PP) plastic, and wrap plastic (clear polyethylene).

2.1. Research Stages

This research was conducted in four steps, namely as follows:

1. Sample Preparation

The sample preparation step consisted of the process of obtaining plastic packaging and taking samples of fresh white chili peppers directly from chili farmers in Sukowono Village. Fresh cayenne peppers aged one day after picking were selected based on the level of maturity and uniform size, namely reddish-orange in color, 3-4 cm long and 1.3 cm wide. The selection of cayenne pepper samples was carried out manually including a sorting process to separate chilies that were defective or damaged, rotten, affected by disease/pests and cleaning chilies from dirt. If the chili is a bit wet, it must be aerated and dried using a cloth/tissue until no water sticks to the outer skin of the chili.

2. Packaging and Storage

Each treatment used 250 g of cayenne pepper. Chili samples will be stored in the refrigerator at a low temperature (5 °C) with different types of packaging (P) and storage time (T). The treatment combinations include:

P1T1: vacuum plastic with storage time of 4 days
P1T2: vacuum plastic with a shelf life of 8 days
P1T3: vacuum plastic with a shelf life of 12 days
P2T1: PP perforated plastic with storage time of 4 days
P2T2: PP perforated plastic with a shelf life of 8 days
P2T3: PP perforated plastic with a shelf life of 12 days
P3T1: wrap plastic with storage time of 4 days
P3T2: wrap plastic with 8 days of storage
P3T3: wrap plastic with 12 days storage

3. Physical Quality Measurement

a) Water content

The procedure for measuring water content is that the sample of cayenne pepper is cut into small pieces and weighed as much as 3 grams. Next, heat the dish in the oven at 105°C for 15 minutes. After being baked, the cup was put in a desiccator for ± 15 minutes, then weighed. After that, the cup containing the sample was heated in an oven at 105 for 6 hours. After being baked, the cup was put in a desiccator for ± 15 minutes, then weighed. The moisture content (KA) is calculated through equation (1):

$$KA\ (\%) = \frac{(b-a)-(c-a)}{(b-a)}\ x\ 100\% \quad (1)$$

where *a* is the weight of the empty cup (g), *b* is the initial weight of the sample and cup (g), and *c* is the final weight of the sample and cup (g).

b) Weight loss

Measurement of chili weight loss was carried out by weighing chili using a digital scale with an accuracy of 0.01 g in order to obtain weight data before and after storage. Material weight loss (*WL*) is calculated using the formula:

$$WL = \frac{A-B}{A}\ x\ 100\% \quad (2)$$

where A is initial weight of sample (g) and B is the weight of the sample on the n^{th} day (g).

c) Texture (Hardness)

Texture measurements were carried out using a penetrometer at three different points, namely, the base, middle, and tip of the chili. The texture of the material can be calculated using the following formula:

$$Pnt = \frac{(g*MK)}{(RP^2*(tan^2 a))} \quad (3)$$

where *Pnt* is penetration pressure (N/mm^2), *g* is gravity (m/s^2), *MK* is the mass of the cone (kg), and *RP* is the mean of texture measurement (mm/kg.s), and *a* angle of penetrometer.

d) Color

Color measurement using the colorimeter tool. Measurements were made by targeting the tool at 3 points, namely the base, middle and tip of the chili so that the values of *L**, *a**, and *b** were obtained and the values of Δ*L**, Δ*a** and Δ*b** were calculated. The determination of the total color change (Δ*E*) is calculated by the formula:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4)$$

e) Water activity

Measurement of water activity was carried out using the LabSwift water activity meter.

2.2. Data Analysis

The research data were processed using Analysis of Variance (ANOVA) two mix factors with a level of = 0.05. The purpose of the Anova test was to determine the significant difference in the overall treatment combination on the physical quality of fresh cayenne pepper. Data analysis using Microsoft Excel 2013 program, and continued with the Tukey test.

3. RESULTS AND DISCUSSION

3.1. Moisture Content

Water content is one of the parameters to calculate the amount of water content contained in a material. The water content greatly affects the shelf life of cayenne pepper or other horticultural products. The results of the water content measurement of cayenne pepper due to variations in the type of packaging and storage time can be seen in Figure 1.

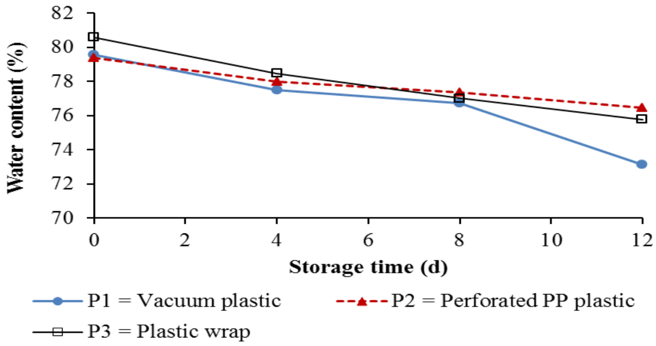

Figure 1. The effect of packaging type and storage time on water content of cayenne pepper

From Figure 1 it is known that during 12 days of storage, the lowest moisture content of cayenne pepper decreased from 79.4% to 76.5% in treatment P2, the highest water content shrinkage from 79.6% to 73.1% in treatment P1 and treatment P3 with a water content value from 80.6% to 75.8%. This shows that the longer the storage time, the water content of cayenne pepper decreases. The decrease in the value of water content is related to the ongoing process of chili metabolism. Fresh cayenne pepper is a structure that is still alive, where before and after being harvested they still carry out metabolic processes, namely respiration and transpiration. The metabolic process of chili during storage results in water loss. Loss of water in a small amount of chili will probably not interfere, but if the amount of water loss is large enough it can cause withering and shrinking of chili.

After the 8th day of storage to the 12th day, in the P1 treatment (vacuum plastic) there was chili water stored in the plastic. The release of chili water occurs due to the respiration process that cannot run optimally. This resulted in the magnitude of the value of the decrease in water content on the length of storage after the 8th day. The impermeable condition of the plastic results in reduced O_2 and the accumulation of CO_2 that exceeds the acceptance limit of the packaged product. Therefore, chilies stored in vacuum plastic will be damaged, shriveled and watery rot. The results of the quality of chili stored in vacuum plastic decreased and were not suitable for consumption. According to Hadisoemarto (2003), if horticultural products are tightly packed using a film sheet that is very impermeable to gas, the oxygen content in the packaging will drop to very low levels so that respiration will switch to an anaerobic process. Anaerobiosis is accompanied by the appearance of an unpleasant odor as a sign of declining quality of the packaged product. This also causes the packaged product to lose a lot of water and the product to lose its freshness due to wilting and wrrinkling.

The P2 packaging type showed the lowest reduction in the water content of cayenne pepper during 12 d of storage, compared to P1 and P3 packaging plastics which are made of PE (polyethylene). The lowest reduction of water content in the P2 treatment indicated that the PP plastic was able to inhibit water transfer during storage. In line with the research of Waryat & Handayani (2020), in pakcoy packaging the lowest water content reduction value was obtained in PP plastic packaging. PP plastic is more able to inhibit water movement because PP plastic has lower permeability than PE. The amount of water vapor passing through PE plastic packaging is greater than PP plastic packaging. The less water vapor that can penetrate a packaging material, the longer the shelf life of the food packaged with the packaging material. The results of Anova two mix factors on the water content of cayenne pepper can be seen in Table 1.

Table 1. The ANOVA of two mix factors on the water content of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	11.543	5.771	3.579	3.555
Storage time	2	38.547	19.274	11.952	3.555
Interaction	4	8.706	2.176	1.350	2.928
Error	18	29.028	1.613		

Table 1 shows that variations in the type of packaging and storage time are significantly different to the moisture content of fresh cayenne pepper. This means that H1 is accepted, so there is an influence between the type of packaging and the length of storage on the value of the moisture content of fresh cayenne pepper. The interaction variation was not significantly different to the value of the water content of fresh cayenne pepper. This means that H0 is accepted, so there is no influence between the interaction on the value of the water content of fresh cayenne pepper. The results of the Tukey test for the water content of cayenne pepper can be seen in Table 2. It was showed that there is a significant difference in the type of packaging treatment in the comparison of P1 vs. P2, but not significantly different in the comparison of P1 vs. P3 and P2 vs. P3. The treatment duration of storage was significantly different in the comparison of 4 vs 12 days and 8 vs 12 days, but was not significantly different in the comparison of storage time for 4 vs. 8 days.

Table 2. Tukey test results on the water content of cayenne pepper

Treatment	Comparation	Absolute Difference	Critical Value
Packing type	Vacuum plastic (P1) vs. perforated PP plastic (P2)	1.470	1.311
	Vacuum plastic (P1) vs. wrap plastic (P3)	1.286	
	Perforated PP plastic (P2) vs. wrap plastic (P3)	0.184	
Storage time	4 vs. 8	0.960	
	4 vs. 12	2.874	
	8 vs. 12	1.914	

3.2. Weight Loss

Weight loss is one of the parameters for decreasing the quality of agricultural products. During the storage process to the cooking process, cayenne pepper loses water which has an impact on weight loss and can cause damage. The weight loss of cayenne pepper with various types of packaging and storage time can be seen in Figure 2. It can be seen that the lowest weight loss of cayenne pepper on the 12th day of storage was 3.87% with P2 treatment, while the highest weight loss value was 5.67% with P1 treatment and P3 treatment with a weight loss value of 4.73%. The increase in weight loss is directly proportional to the length of storage, where the longer the storage time, the weight loss of cayenne pepper will increase. The increase in weight loss of cayenne pepper with storage time is caused by the respiration process which causes the chili to release water and the transpiration process through the surface of the fruit skin which is still ongoing after the chili is harvested. This increase is due to the respiration process, namely the conversion of carbohydrates with the help of oxygen into carbon dioxide and water vapor. The decrease in carbohydrate content causes the loss of some of the substrate in cayenne pepper, so that the weight of cayenne pepper decreases (Sulistyaningrum & Darudriyo, 2018).

The P2 type of packaging treatment showed the lowest weight loss of cayenne pepper during 12 days of storage, compared to treatments P1 and P3. Thus, P2 treatment proved to be more effective in inhibiting chili weight loss during storage. PP plastic has low permeability, so it can suppress the release of oxygen, carbon dioxide, and water vapor into the environment. This can inhibit the occurrence of water loss so that the cayenne pepper packaged in packaging still looks fresh. This is in accordance with the research of Wulandari *et al.* (2012) where polypropylene (PP) plastic is one type of plastic packaging that is not easily torn, waterproof, not easily passed (impermeable) by gas and water vapor so that water does not easily come out of cayenne pepper. The results of the Anova two mix factors on the weight loss of cayenne pepper can be seen in Table 3.

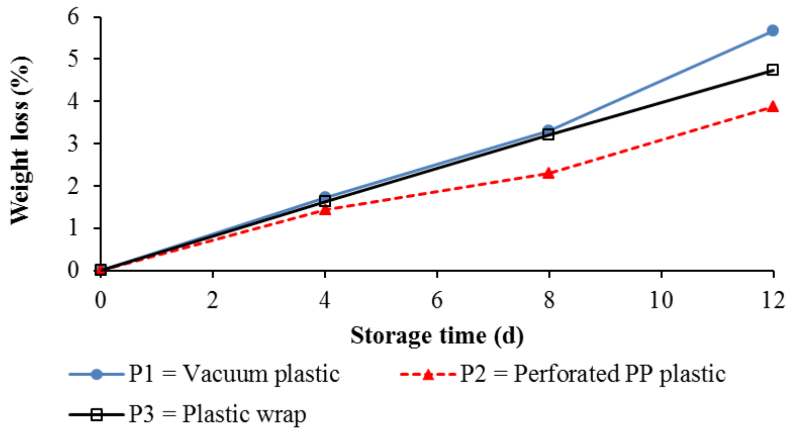

Figure 2. The effect of packaging type and storage time on the weight loss of cayenne pepper

Table 3. ANOVA of two mix factors on the weight loss of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging type	2	4.842	2.421	14.698	3.555
Storage time	2	45.304	22.652	137.518	3.555
Interaction	4	1.943	0.486	2.949	2.928
Error	18	2.965	0.165		

The results of the Anova two mix factors test showed that variations in the type of packaging, storage time, and interactions were significantly different to the weight loss of cayenne pepper. This means that H1 is accepted, so there is a significant effect of the type of packaging, storage time, and interaction on the weight loss of cayenne pepper. The results of the Tukey test (Table 4) show that there is a significant difference in the type of packaging treatment in the comparison of P1 vs. P2 and P2 vs. P3. But not significantly different in the comparison of P1 vs. packaging types. P3. As for the treatment duration of each storage was significantly different, namely the comparison of day 4 vs. 8, 4 vs. 12, and 8 vs. 12.

Table 4. Tukey's test results on the weight loss of cayenne pepper

Treatment	Comparation	Absolute difference	Critical value
Packaging type	Vacuum plastic (P1) vs. perforated PP plastic (P2)	1.024	
	Vacuum plastic (P1) vs. wrap plastic (P3)	0.371	
	Perforated PP plastic (P2) vs. wrap plastic (P3)	0.653	0.419
Storage time	4 vs. 8	1.343	
	4 vs. 12	3.161	
	8 vs. 12	1.818	

3.3.Texture (Hardness) of Cayenne Pepper

Texture (level of hardness) is closely related to the quality of cayenne pepper, which can determine whether or not it is suitable for consumption. According to Blongkod *et* *al.* (2016), a penetrometer is a tool used to measure the hardness of a material by inserting a needle into the tissue. The deeper the needle penetration indicates the softer the tissue. The results of the texture measurement of cayenne pepper due to variations in the type of packaging and storage time can be seen in Figure 3. It can be observed that on the 12th day of storage, fresh cayenne pepper has the highest texture value of 0.027 N/mm² in treatment P2, while the lowest texture value is 0.017 N/mm² in treatment P1 and treatment P3 with a texture value of 0.020 N/mm². Cayenne pepper decreased in texture (level of hardness) along with storage time. The greater the value of decreasing the hardness of the chili, it indicates that the texture of the chili is getting softer. According to Widhiantari *et al.* (2016), the level of fruit damage will affect the texture value. The lower the value of the fruit texture, the lower the quality of the fruit. Vice versa, the higher the texture value, the better the quality of the fruit. The texture of the fruit shows the level of freshness of the fruit, where the lower the value of the texture of the fruit, the freshness of the fruit also decreases. Texture value is related to the magnitude of the force issued by the penetrometer needle to penetrate the surface of the material. The higher the texture value, the harder the cayenne pepper surface. Conversely, the lower the texture value, it indicates the surface of the cayenne pepper is getting softer, so that with a little force the penetrometer needle will be able to penetrate the surface of the chili. The level of hardness of a material is related to the content in the material. Lamona *et al.* (2015) stated that hardness level depends on the thickness of the outer shell, the total solids content and the starch content in a material.

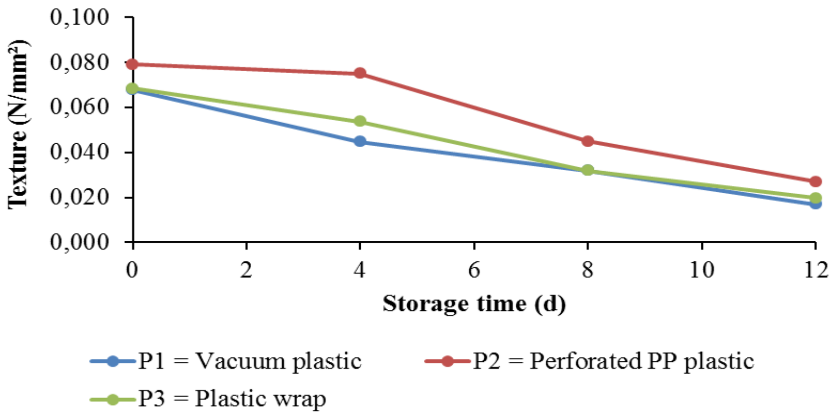

Figure 3. The effect of packaging type and storage time on the hardness of cayenne pepper

The P2 type of packaging treatment showed the highest texture value (level of hardness) of cayenne pepper during 12 days of storage, compared to treatments P1 and P3. The addition of holes (perforation) in the P2 treatment became a place for air exchange resulting from respiration and transpiration of cayenne pepper during storage. Thus, the results of respiration and transpiration do not make the chili more saturated with water vapor and can avoid damage due to the buildup of CO_2 in the packaging which can cause the chili to quickly rot and soften the fruit. According to Widianty (2015), generally for packaging horticulture, holes need to be made for ventilation so that it can maintain its quality when used in conjunction with refrigeration. Perforations with holes will allow sufficient O_2 entry and avoid damage due to CO_2.

Table 5. ANOVA of two mix factors on the hardness level of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	1.57E-03	7.86E-04	25.178	3.555
Storage time	2	6.07E-03	3.04E-03	97.263	3.555
Interaction	4	3.83E-04	9.57E-05	3.066	2.928
Error	18	5.62E-04	3.12E-05		

The results of the Anova two mix factors test (Table 5) showed that variations in the type of packaging, storage time, and interactions were significantly different to the texture value of cayenne pepper. This means that H1 is accepted, so there is a significant effect of the type of packaging, storage time, and interaction on the value of cayenne pepper. Based on the Tukey test (Table 6), it can be seen that for the type of packaging treatment there is a significant difference in the comparison of P1 vs. P2 and P2 vs. P3. But not significantly different in the comparison of P1 vs. packaging types. P3. As for the treatment duration of each storage was significantly different, namely the comparison of day 4 vs. 8, 4 vs. 12, and 8 vs. 12.

Table 6. Tukey's test results on the hardness level of cayenne pepper

Treatment	Comparation	Absolute Difference	Critical Value
Packing type	Vacuum plastic (P1) vs. perforated PP plastic (P2)	0.018	0.006
	Vacuum plastic (P1) vs. wrap plastic (P3)	0.004	
	Perforated PP plastic (P2) vs. wrap plastic (P3)	0.014	
Storage time	4 vs. 8	0.021	
	4 vs. 12	0.037	
	8 vs. 12	0.015	

3.4. Color Change

Changes in color can indicate the level of maturity and freshness, so that it can affect consumer interest in choosing products such as cayenne pepper. The color change of cayenne pepper during storage was assessed using the Hunter notation system which is characterized by three color parameters, namely the notation *L**, *a**, and *b**. Visually, the use of various types of packaging in this study did not have a significantly different effect on changes in the color of cayenne pepper during storage. This is in line with the research results of Nurdjannah *et al.* (2014) where the type of packaging factor does not really have a significant effect on changes in the color value of red chili. This could be due to the non-climacteric characteristics of chili peppers. Non-climacteric horticultural products did not show significant changes in the ripening phase because the respiration process in the product was slow. Including the process of overhauling the chili skin pigment.

A very noticeable change in the color of cayenne pepper occurred on the 12th day of storage in vacuum plastic packaging, where the chili turned dark reddish along with dry, wilted, and blackish stems due to many chilies that were in a watery rot condition. The color change of cayenne pepper in various types of packaging can be seen in Figure 4.

Figure 4. Color changes of cayenne pepper in different types of packaging and storage time

3.4.1. Value L (Lightness)*

The value of L* indicates the level of lightness where *L**= 0 (black) and *L**= 100 (white) (Wulandari, 2019). The change of *L** value of cayenne pepper with variations in the type of packaging and storage time can be seen in Figure 5. It can be seen that during 12 days of storage there was the highest decrease in the *L** value of cayenne pepper from 46.85 to 43.79 in treatment P1, while the lowest decrease in *L** value from 46.62 to 44.52 in treatment P2, and treatment P3 with an *L** value from 46.23 to 44.12. The cause of the decrease in the value of L* (brightness level) is because cayenne pepper has a red color, especially during fruit aging which comes from carotenoid pigments which can increase along with the respiration process in the fruit during storage. According to David (2018), the red color of chili is caused by the presence of carotenoid pigments whose colors vary from yellow orange to dark red.

The decrease in the value of *L** causes the color of the cayenne pepper to be darker the longer it is stored. According to Susilowati (2008), this is because the fruit is still carrying out the respiration process to the decay process even though it has been harvested. The results of the Anova two mix factors test on the L value of cayenne pepper (Table 7) showed that the variation of storage time was significantly different to the *L** value of fresh cayenne pepper. This means that H1 is accepted, so there is an influence between storage time on the L value of fresh cayenne pepper. In the variety of packaging types and interactions, there was no significant difference in the L value of fresh cayenne pepper. This means that H1 is rejected, so there is no influence between the type of packaging and the interaction on the L value of fresh cayenne pepper. Tukey's test (Table 8) shows that for each storage time treatment is significantly different, namely the comparison of 4 vs. 8, 4 vs. 12, and 8 vs. 12 days.

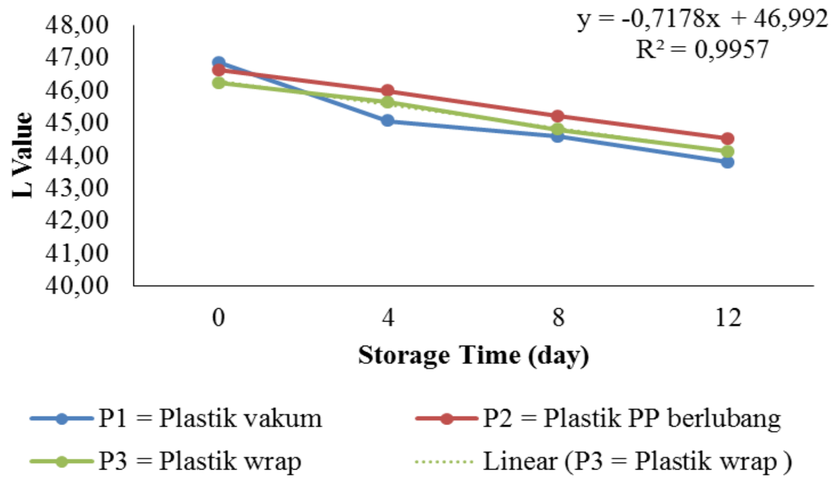

Figure 5. The effect of packaging type and storage time on the lightness (*L**) of cayenne pepper

Table 7. ANOVA of two mix factors on the lightness (*L**) of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	2.561	1.281	3.192	3.555
Storage time	2	9.046	4.523	11.275	3.555
Interaction	4	0.118	0.029	0.073	2.928
Error	18	7.221	0.401		

Tabel 8. Tukey's test results on the lightness (*L**) of cayenne pepper

Treatment	Comparation	Absolute Difference	Critical Value (HSD)
Storage time	4 vs. 8	0.699	0.654
	4 vs. 12	1.418	
	8 vs 12	0.719	

3.4.2.Redness Level (a)*

The value of *a* indicates the chromatic color of the red-green mixture, namely, +*a** which indicates red with a value of 0 to 60, while –*a** indicates a green color with a value of 0 to –60 (Wulandari, 2019). Figure 6 presents the chroma a value of cayenne pepper during storage with various types of packaging.

Based on the graph in Figure 6, it is known that during storage there was an increase in the highest *a** value of cayenne pepper from 24.58 to 27.70 in treatment P1, while the lowest increase in a value from 24.82 to 26.97 in treatment P2, and treatment P3 with the value of *a** from 24.64 to 27.34. The lower *a** value in cayenne pepper indicates a low reddish color intensity, while the higher *a** value indicates a high reddish color intensity or darker color. An increase in the *a** value of cayenne pepper indicates a reddish fruit change that occurs as the fruit ripens during storage.

Reddish discoloration during storage is influenced by carotenoid pigments in cayenne pepper. According to Siswati (2009), color changes during storage are caused by the activity of microorganisms that cause damage to the red pigment as a result of cutting the pigment structure into other simpler components so that the color changes to dark.

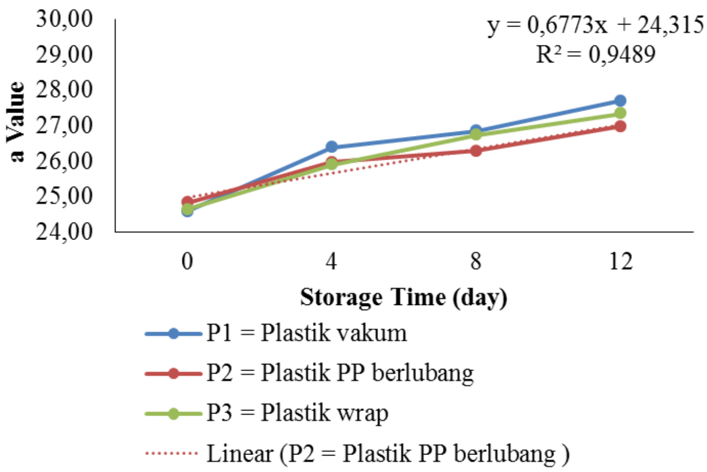

Figure 6. The effect of packaging type and storage time on the redness (*a**) of cayenne pepper

The Anova two mix factors test (Table 9) showed that the variation of storage time was significantly different to the *a** value of fresh cayenne pepper. This means that H1 is accepted, so there is an influence between storage time on the *a** value of fresh cayenne pepper. For variations in the type of packaging and interactions, there was no significant difference to the *a** value of fresh cayenne pepper. This means that H1 is rejected, so there is no influence between the type of packaging and the interaction on the a value of fresh cayenne pepper. Based on Tukey's test on the *a** value of cayenne pepper (Table 10) it was concluded that the storage time treatment for each was significantly different, namely the comparison of day 4 vs. 8, 4 vs. 12, and 8 vs. 12.

Table 9. ANOVA of two mix factors on the redness (*a**) of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	1.470	0.735	2.862	3.555
Storage time	2	7.156	3.578	13.926	3.555
Interaction	4	0.279	0.070	0.272	2.928
Error	18	4.624	0.257		

Table 10. Tukey's test results on the redness (*a**) of cayenne pepper

Treatment	Comparation	Beda Absolut	Critical Value (HSD)
Storage time	4 vs. 8	0.538	0.523
	4 vs. 12	1.257	
	8 vs 12	0.719	

3.4.3.Yellowness Level (b)*

The *b** value indicates a mixed blue-yellow chromatic color, namely, +*b** which indicates yellow with a value of 0 to 60, while –*b** indicates blue with a value of 0 to –60 (Wulandari, 2019). Figure 7 shows the *b** value of cayenne pepper due to variations in the type of packaging and storage time. It can be seen that on the 0th day of storage (initial conditions) to 12 days after storage there was an increase in the highest cayenne pepper *b** value in treatment P1 from 8.69 to 11.69. Meanwhile, the lowest increase in the *b** value of cayenne pepper was in treatment P2 from 9.12 to 10.97, and treatment P3 from 9.04 to 11.49. An increase in the *b** value of cayenne pepper during storage indicated that fresh cayenne pepper had a yellowish color change. According to Kumalaningsih *et al.* (2012), browning is a process of formation of a yellow pigment and immediately changes to a dark brown color. The formation of this brown color can be triggered by the oxidation reaction of the phenol enzyme.

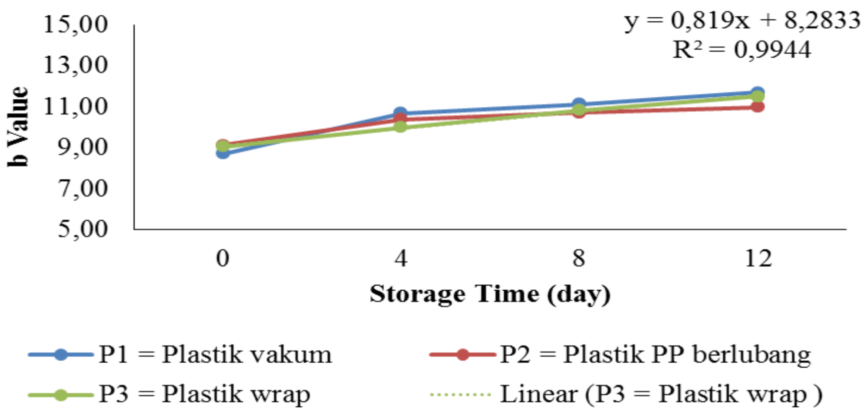

Figure 7. Effect of packaging type and storage time on the yellowness (*b**) of cayenne pepper

Table 11. ANOVA of two mix factors on the yellowness (*b**) of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	1.159	0.579	2.826	3.555
Storage time	2	4.870	2.435	11.875	3.555
Interaction	4	0.675	0.169	0.823	2.928
Error	18	3.691	0.205		

Table 12. Tukey's test results on the yellowness (*b**) of cayenne pepper

Treatment	Comparation	Beda Absolut	Critical Value (HSD)
Storage time	4 vs. 8	0.540	0.468
	4 vs. 12	1.040	
	8 vs 12	0.500	

Based on the Anova two mix factors test on the *b** value of cayenne pepper (Table 11) it can be observed that the variation of storage time is significantly different to the *b** value of fresh cayenne pepper. This means that H1 is accepted, so there is an influence between storage time on the *b** value of fresh cayenne pepper. The variation of the type of packaging and the interaction did not significantly differ on the *b** value of fresh cayenne pepper. This means that H1 is rejected, so there is no influence between the type of packaging and the interaction on the *b** value of fresh cayenne pepper. The results of the Tukey test for the *b** value of cayenne pepper (Table 12) showed that the storage time for each treatment was significantly different, namely the comparison on day 4 vs. 8, 4 vs. 12, and 8 vs. 12.

3.4.5. Total Color Change

The total color (E) of cayenne pepper for all treatments during storage obtained different values (Figure 8). The greatest total color change value (ΔE) was found in treatment P1 from 22.54 to 43.12. Meanwhile, the lowest total color change was found in treatment P2 from 5.92 to 23.47. In the P3 treatment, the value of E was 8.53 to 30.45. The P2 treatment resulted in the least total color change. In accordance with the research of Putri *et al.* (2020), storage of curly red chili using PP packaging resulted in the least color change. This is because PP has the best performance and permeability in retaining water vapor. The combination of the temperature of the PP packaging can reduce the occurrence of water evaporation so that the brightness level is higher than chili stored in mica (PET) and wrap plastic packaging.

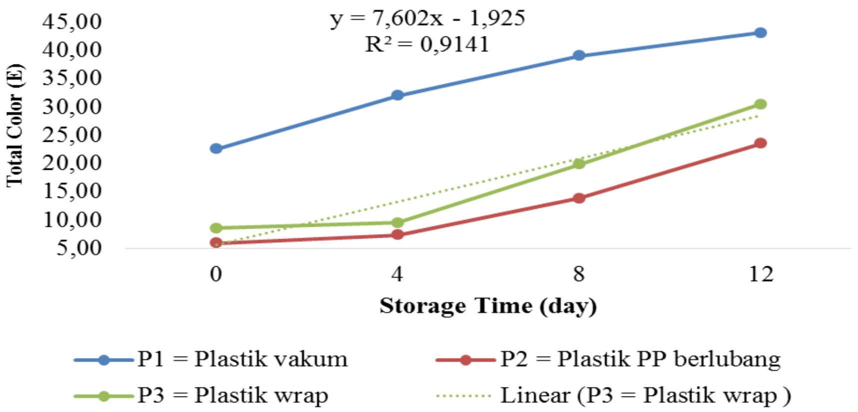

Figure 8. Effect of packaging type and storage time on the total color (*E*) of cayenne pepper

Based on the results of the Anova two mix factors test (Table 13) it can be observed that variations in the type of packaging and storage time are significantly different to the ΔE value of fresh cayenne pepper. This means that H1 is accepted, so that there is an influence between the type of packaging and the length of storage on the ΔE value of fresh cayenne pepper. The interaction variation was not significantly different from the E value of fresh cayenne pepper. This means that H1 is rejected, so there is no influence between the interactions on the ΔE value of fresh cayenne pepper. The results of the Tukey test for the value of ΔE of cayenne pepper (Table 14) show that in the type of packaging treatment there is a significant difference in the comparison of P1 with P3. But it was not significantly different in the comparison of P1 with P2 and P2 with P3 packaging types. While in the treatment of each storage time significantly different, namely the comparison of day 4 vs. 8 and 4 vs. 12, but not significantly different in the comparison of day 8 vs. 12.

Table 13. ANOVA of two mix factors on the total color (*E*) of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	2669.738	1334.869	12.454	3.555
Storage time	2	1167.491	583.746	5.446	3.555
Interaction	4	79.067	19.767	0.184	2.928
Error	18	1929.382	107.184		

Table 14. Tukey's test results on the total color (*E*) of cayenne pepper

Treatment	Comparation	Absolute	Critical
Packing type	Vacuum plastic (P1) vs. perforated PP plastic (P2)	7.938	10.691
	Vacuum plastic (P1) vs. wrap plastic (P3)	16.107	
	Perforated PP plastic (P2) vs. wrap plastic (P3)	8.169	
Storage time	4 vs. 8	23.166	
	4 vs. 12	18.100	
	8 vs. 12	5.066	

3.5. Water Activities of Cayenne Pepper

Water activity (A_w) of foodstuffs is the amount of free water contained in foodstuffs, which can be used by microbes for their growth (Sakti *et al.*, 2016). Water activity is one of the factors that affect food spoilage because it describes the microbial need for water. The results of the measurement of the A_w value (Figure 9) showed that the water activity of cayenne pepper on the 12th day of storage experienced the highest increase of 0.891 with treatment P1, while the lowest A_w value in treatment P2 was 0.889 and treatment P3 with an Aw value of 0.890. The increase in the A_w value of cayenne pepper in all types of packaging treatments during storage was caused by the metabolic processes of microorganisms in the ingredients. According to (Sakti *et al.*, 2016), the increase in water activity is due to the metabolism of microorganisms which is generally followed by the release of water, resulting in an increase in A_w in food materials.

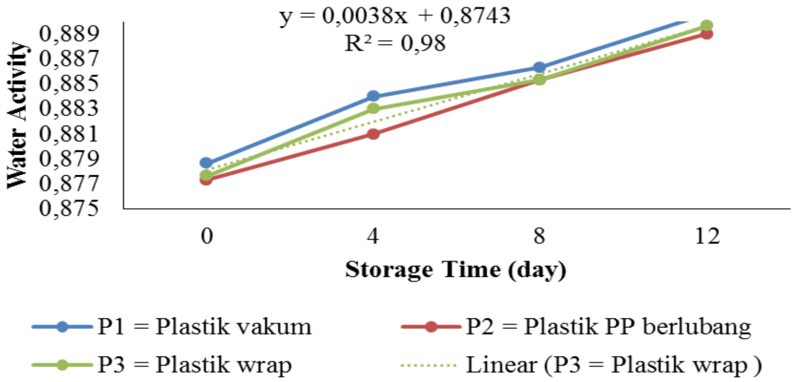

Figure 9. Effect of packaging type and storage time on the water activity of cayenne pepper

Analysis of the A_w value is used to show the growth of certain types of microbes that grow, this is related to the durability and safety of cayenne pepper. The Aw value of cayenne pepper for 12 days of storage was in the range of 0.8-0.9. This implies that the microorganism that grows and develops in cayenne pepper is probably a type of yeast. According to Sari *et al.* (2017), water activity is very influential on microbial growth, the minimum requirements for microbes to live for bacteria are 0.9, yeast (0.80 -0.90), and molds (0.60-0.70).

Table 15. ANOVA of two mix factors on the water activity (A_w) of cayenne pepper

Variation source	Degree of freedom	Sum of squares (SS)	Mean of squares (MS)	F-Calculated (F)	F-Table (F crit)
Packaging types	2	1.61E-05	8.04E-06	3.056	3.555
Storage time	2	2.29E-04	1.15E-04	43.620	3.555
Interaction	4	4.15E-06	1.04E-06	0.394	2.928
Error	18	4.73E-05	2.63E-06		

Based on the results of the Anova two mix factors test (Table 15) it was concluded that the variation of storage time was significantly different to the water activity value of fresh cayenne pepper. This means that H1 is accepted, so there is an influence between storage time on the value of fresh cayenne pepper water activity. In the variety of packaging types and interactions, there was no significant difference in the water activity value of fresh cayenne pepper. This means that H1 is rejected, so there is no effect between the type of packaging and the interaction on the value of the water activity of fresh cayenne pepper. The results of the Tukey test on the water activity of cayenne pepper (Table 16) showed that the storage time treatment for each was significantly different, namely the comparison of days 4 vs. 8, 4 vs. 12, and 8 vs. 12.

Table 16. Tukey's test results on the water activity (A_w) of cayenne pepper

Treatment	Comparation	Absolut Difference	Critical Value (HSD)
Storage time	4 vs. 8	0.003	0.002
	4 vs. 12	0.007	
	8 vs 12	0.004	

4. CONCLUSIONS AND SUGGESTIONS

The type of packaging treatment affects the physical quality of fresh cayenne pepper during storage at low temperatures (5 °C) including water content, weight loss and texture which show significantly different physical quality values. While the storage time treatment has an effect on water content, weight loss, texture, color changes L^*, a^*, b^* and water activity which shows significantly different physical quality values. The best type of packaging treatment to maintain the physical quality of fresh cayenne pepper for up to 12 days of storage at a low temperature (5 °C) was in the type of perforated PP plastic packaging with the lowest moisture content loss value of 76.45%, the lowest weight loss of 3.87% , the highest texture (hardness level) is 0.027 N/mm^2, the highest color lightness (L^*) is 44.52, the lowest a^* value is 26.97, the lowest b^* value is 10.97, the lowest E value is 23.47, and the lowest water activity value is 0.889. The 12th day of storage is the limit of the shelf life of the three samples, namely P1, P2 and P3 because they are not suitable for consumption with the physical condition of chilies that are rotting and watery. There needs to be a special place or other equipment to measure color. This is because when measuring the color of the material, it requires a place with stable light conditions. In addition, further research on the effect of the number and size of the packaging perforation holes needs to be done because this is related to the value of the moisture content and texture of stored cayenne pepper.

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