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Starfruit Maturity Stages and Fruit Packaging Type for Preserving Quality During Distribution

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Abstract

One effort that can be made to reduce starfruit damage is harvesting at the right stage of maturity and choosing the proper packaging. The research objective was to obtain the right maturity stage and type of packaging to reduce the percentage of damage and preserve quality during the distribution process of starfruit. The research was carried out at the Trilogi University. The harvesting and packaging process was carried out at Attaqie Farm, East Java. The study was conducted from October 2022 to March 2023. The method used was a Completely Randomized Design with two factors; the first factor was the stage of maturity (S), consisting of 2 levels: S-4 and S-5). The second factor was the type of packaging composed of 4 levels: cardboard packaging (fruit sealed with newspaper); cardboard packaging (fruit sealed with newspaper and foam net); basket packaging (fruit sealed with newspaper); and basket (fruit sealed with newspaper and foam net), replicated three times. The variables observed were the percentage of fruit damage, °Hue value, taste scoring, Total Dissolved Solids (TDS), and Total Titratable Acidity (TTA). The research results showed that starfruit could still be accepted by consumers until the 6th day, with the best treatment in SK-4, which is basket packaging type (fruit sealed with newspaper and foam net). This treatment had good results, as indicated by the damage percentage value of 7.67%, taste score of above 3.5, TDS of 9.66, °Hue value of 99.89 with less bright colors, and TTA of 0.50.

Keywords: fruit distribution, fruit packaging, fruit storage, post-harvest ,tropical fruit

1. Introduction

Starfruit (*Averrhoa carambola*), commonly called starfruit, is a non-climacteric fruit that has smooth skin and a short shelf life. Starfruit is susceptible to damage when in distribution and storage. This is due to the nature of starfruit, which has thin skin that can easily bruise, making the transpiration process occur more quickly. In the delivery process (distribution) of starfruit, there is also a high risk of damage. If the distribution distance to the destination (market/consumer) is far, this will result in a decrease in quality and an increase in the percentage of damage during transit. So, efforts are needed to preserve the quality of starfruit.

Damage to starfruit is characterized by the presence of brown spots on the surface of the fruit and the browning of the fins of the starfruit. Damage to starfruit will continue to occur and cause increasingly severe damage, especially with increasing travel time and storage time during the starfruit distribution process. The impact that will arise from damage to the starfruit is that the starfruit will change color to brown, and the water content, weight, and quality of the starfruit will decrease. This can have a negative impact on the price of starfruit. Therefore, treatment is needed to preserve the quality of starfruit so that it can last longer from delivery to consumers. This can be achieved by harvesting starfruit at the right stage of maturity and by choosing the proper packaging to reduce the level of damage to the starfruit.

The Central Bureau of Statistics data (2022) shows that East Java province is the region with the highest starfruit production, with production reaching 64,856 tons. According to Amirulah (2012), there are six classifications of starfruit maturity indices. The fruit used in this research was fruit with maturity stages 4 and 5, which means the fruit was ready to be marketed and consumed. The distance and duration of transportation to reach the market were different, so the stage of maturity needed to be adjusted to meet the transportation duration and consumer needs (Sumiasih and Nurainani, 2023).

Starfruit (*Averrhoa carambola*) is a fruit that is easily damaged if exposed to shocks during travel. So, apart from the maturity stage, there needs to be appropriate packaging to preserve the quality until the fruit reaches the consumers. There are various ways to package starfruit to reduce damage and maintain quality, such as using cardboard, newspaper, and foam net. The function of packaging is to contain and protect the starfruit from harm so that it is easier to store, transport, and market to consumers. Furthermore, packaging has many benefits, including protecting and preserving products, increasing efficiency, protecting against external damaging factors, and expanding product marketing. Packaging is chosen by considering the most critical factor, namely the permeability properties of the packaging material (Nasution *et al.* 2013; Sumiasih *et al.* 2016).

In the preliminary study conducted at the beginning of this experiment, initial trials for packaging materials used wooden crates and baskets weighing 40 kg per package for starfruit. However, upon arrival at the destination (from Tuban to Jakarta), the damage rate showed a still high percentage of 30%. Therefore, in this study, cardboard boxes and baskets weighing 5 kg each per package are used instead. Packaging fruit in cardboard is one way to reduce the respiration rate of the fruit. Respiration is the process of breaking down organic matter in stored fruit, such as carbohydrates, fats, and proteins, into energy. Respiration can lead to depletion of food reserves and accelerate fruit spoilage because the fruit's food reserves are converted into energy, reducing nutritional content and diminishing sweetness.

Plastic baskets are containers made from plastic materials used for storing or transporting various types of goods or products. The use of plastic baskets is an innovation that can be easily integrated into daily life, including fruit storage. Plastic fruit baskets are specifically designed for storing and transporting fruits. These baskets usually have ventilation or small holes on each side to facilitate air circulation around the fruit. The ventilation in fruit baskets helps prevent moisture buildup, which can otherwise lead to fruit spoilage. Based on research by Djaafar et al. (2022) on Pondoh snake fruit, the use of basket packaging can reduce weight loss caused by maintaining moisture and slowing down the transpiration process. The research objectives were to obtain the right stage of maturity and type of packaging to reduce the percentage of damage and preserve quality during the distribution process of starfruit.

2. Materials and Methods

This research was carried out at the Agroecotechnology Laboratory of Trilogi University. The harvesting and packaging process was carried out at Attaqie Farm, East Java. This research was conducted in October 2022 - March 2023.

The tools used in the research were scales, color readers, hand refractometers, burettes, states, Erlenmeyer tubes, measuring cups, pipettes, scalpels, and baker's glasses. The materials used in this research were Tasikmadu starfruit, maturity stages 4 and 5, newspaper, foam net, NaOH, distilled water, and phenolphthalein.

This research used a Completely Randomized Design with two factors. The first factor was the maturity stage, which consists of 2 levels, namely maturity stage 4 (S1) and maturity stage 5 (S2). The second factor was the type of packaging composed of 4 levels, namely: cardboard packaging (fruit sealed with newspaper) (K1); cardboard packaging (fruit sealed with newspaper and foam net) (K2); basket packaging (fruit sealed with newspaper) (K3); and basket (fruit sealed with newspaper and foam net) (K4), Each treatment uses three pieces of starfruit and replicated three times, observations are conducted for eight days after harvest.

According to Amirulah (2012), the previous maturity classification standard it was only six maturity levels. These six indexes of starfruit are shown in Table 1. The fruit used in this research was fruit with maturity stages 4 and 5.

 Index 1	**Dark Green** Fruit is immature. Not suitable for harvesting or exporting.	 Index 2	**Green with a little yellow** Matured. Suitable for harvesting and export trough sea.
 Index 3	**Green more than yellow** Matured. Suitable for harvesting and export trough sea.	 Index 4	**Yellow green** For export using air transport.
 Index 5	**Yellow with a little green** Still can be sent for far export using air transport.	 Index 6	**Orange** Not suitable for far export. Local market only.

Table 1. Starfruits Index/maturity stages

This research used observations carried out every two days for nine days after harvest (HSP), which consisted of testing: percentage of fruit damage, *°Hue* Value, taste scoring, Total Dissolved Solids (TDS), and Total Titratable Acidity (TTA).

A. Damage percentage

In this study, the percentage of damage to starfruit is scored based on the following categories and then calculated using the formula for the percentage of damage:

1) Very Bad: There are a lot of impacts on the skin and fins of the starfruit (≥ 40%)

2) Bad: Fins and skin of the starfruit have many impact marks (31% - 40%)

3) Fairly Good: There are some impact marks on the fins and skin of the starfruit (21% - 30%)

4) Good: The skin of the starfruit is smooth, but there are a few impact marks on the fins and skin (11% - 20%)

5) Very Good: The skin and fins of the starfruit are smooth (0% - 10%)

B. *°Hue* Value

The °Hue value was obtained using the hunter color system (L, a, and b). The measurement results were expressed in CCI and hue degrees. The hunter color system was divided into three parameters, namely the notation L for lightness, notation A representing a mixture of red-green colors, and b representing a mixture of blue-yellow colors. The measurement results were converted in hue degrees with the following equation:

$$°\mathrm{Hue} = \tan - 1\ \left(\frac{a}{b}\right)$$

C. Taste Scoring

The taste scoring test in this study used five non-permanent panelists from the start of the test to the end of the test. The starfruit taste was assessed using five ratings, namely: 1) strongly dislike, 2) Dislike, 3) Mildly dislike, 4) Like, and 5) Really Like.

D. Total Dissolved Solid (TDS)

Measurements of Total Dissolved Solid were carried out by taking starfruit juice from each sample and dropping it on the hand refractometer reader lens, and then the numbers were displayed on the screen (Sumiasih *et al.* 2016). TDS levels were measured by °Brix units (Widodo *et al.* 2019).

E. Total Titratable Acidity (TTA)

The analysis of Total Titratable Acidity (TAT) is conducted based on the Indonesian National Standard (SNI) of 2009. Measurements of Total Titratable Acidity were carried out by crushing the starfruit, taking 10 g of the juice, and adding distilled water to 100 mL. Next, 25 mL of the solution was taken, and three drops of phenolphthalein indicator were added and titrated with 0.1 N NaOH. Measurements were carried out using titration. The TTA content was calculated using the formula:

$$\frac{\mathrm{TTA} = \mathrm{V\ x\ n\ NaOH\ x\ Fp\ x\ BE}}{\mathrm{W}}\ \mathrm{x}\ 100\%$$

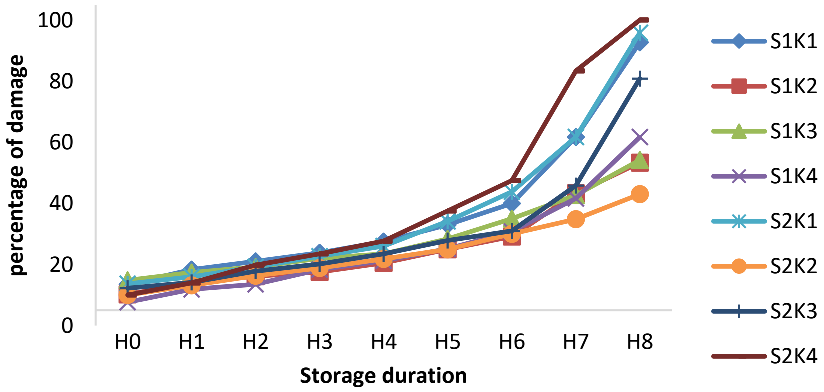
Notes:

TTA	= Total Titratable Acidity	Fp	= dilution factor
V	= volume of NaOH 0.1 N (mL)	BE	= equivalent weight of citric acid (64)
n NaOH	= normality of NaOH (0.1 N)	W	= weight (mg)

3. Results and Discussion

Starfruit Percentage of Damage

Starfruit damage scoring during distribution was assessed when the starfruit arrived at the destination. In this study, the distribution took 11 hours, so it came on the same day as the starfruit harvest (Figure 1).



Description: H0: Day-1, H2: Day-2,.. H8: Day-8

Figure 1. The percentage of damage on starfruit with different treatments

The percentage of damage was assessed by scoring numbers 1 to 5 with a percent range of 0 – 100%; the higher value indicates that the starfruit had a lot of damage, and the lower value indicates that the starfruit had experienced suffered minor damage. The lowest damage value when the fruit first arrived or at 0 days after harvest (DAH) was on the S1K4 treatment. This result showed that in the starfruit distribution process to the research location, fruit with maturity stage 4 had a better shelf life. This was thought to be because the starfruit was firmer when compared to maturity stage 5.

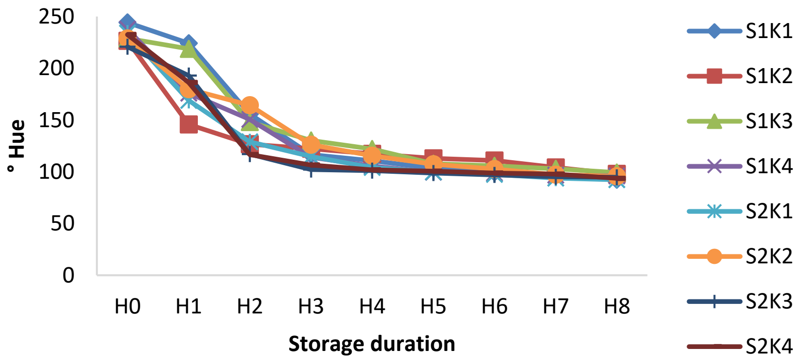
The basket packaging treatment (the fruit was sealed with newspaper and foam net) increased the durability of the fruit while traveling. The solid nature of the basket made it more durable. Furthermore, the addition of newspaper and foam net reduced fruit friction during distribution, thus minimizing damage to the fruit. According to Suryani & Arumsari (2020), the objective of using a foam net is to protect the fruit from coming into direct contact with the surface of other objects, which can cause dents and rot.

At 8 DAH (Figure 1), the percentage of damage to starfruit with the lowest graphic line was found in the maturity stage 5 treatment with cardboard packaging (fruit sealed with newspaper and foam net) (S5K2). This result was because the outer packaging of fruit using cardboard has good results when compared to baskets for storing fruit. This was because cardboard can restrain the rate of respiration in fruit; it keeps oxygen from entering so that the fruit does not spoil quickly. According to Tranggono & Sutardi (1990), the shelf life of fruit will last longer when the respiration rate in fruit is low, and it will be more easily damaged when the respiration rate is higher.

°*Hue* Value

The °Hue value is a measurement of the wavelength by looking at the dominant color that can be seen by sight (Kusumanto *et al.* 2011). Tasikmadu starfruit with maturity stage 4 in the cardboard + newspaper packaging treatment had the highest °Hue value compared to other treatments. It was suspected that starfruit with this treatment had a better ability to maintain the brightness of the color of the starfruit, as shown in Figures 2 and 3. This was thought to be because it was packed with cardboard, and the rate of respiration in the fruit was lower due to cardboard material that restricts air circulation so that the °Hue value or color brightness of the fruit can be maintained well. According to Pangestuti *et al.* (2016), a lower rate of respiration in fruit will cause the breakdown of organic acids to occur more slowly; the sugar content will increase more slowly.

The most significant decrease in °*Hue* occurred at 0 to 1 DAH in the S1K2 treatment. However, from 2 days until the end of storage, it was observed that this treatment was able to maintain color better than the other treatments. This result was thought to be because collective packaging can cause fruit to ripen more quickly and cause the °Hue of the fruit to decrease drastically. This had been observed in other fruits, namely mangoes, by Afrianti (2013), who explained that storing mangoes at room temperature and in collective packaging causes the respiration rate to occur faster and causes color changes in the fruit to happen more quickly. Changes in fruit color would cause the brightness of the fruit to decrease so that the °Hue value of the fruit also reduces drastically. The fruit ripening process is related to cell membrane degradation; the enzyme that plays a role is the phospholipase D enzyme.



Description: H0: Day-1, H2: Day-2,.. H8: Day-8
Figure 2. The °Hue value of Tasikmadu starfruit in different treatments of maturity stages and packaging type

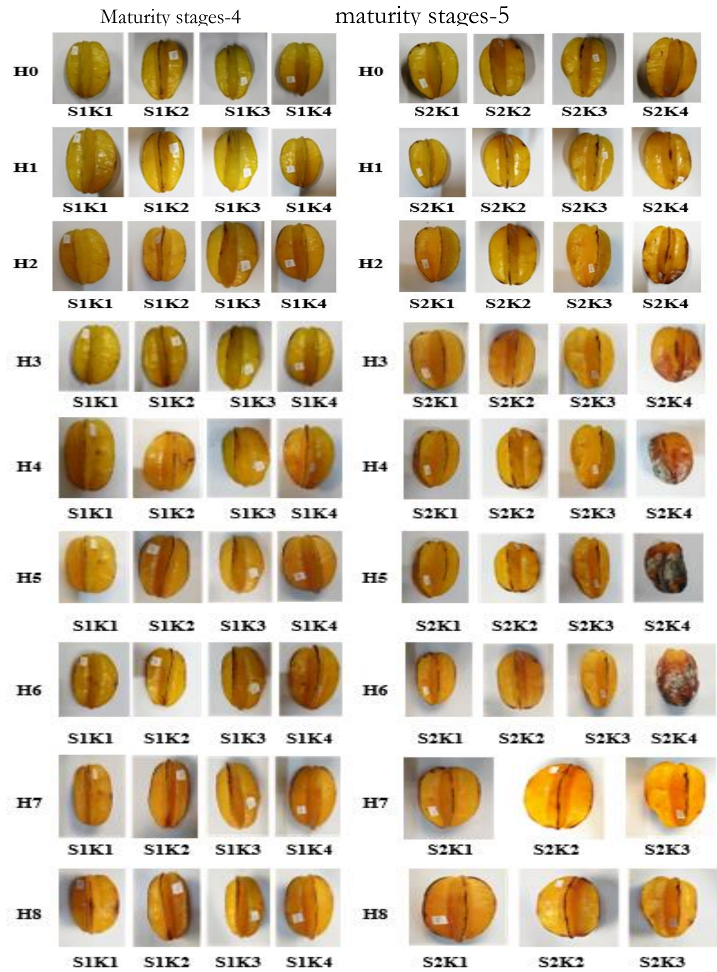
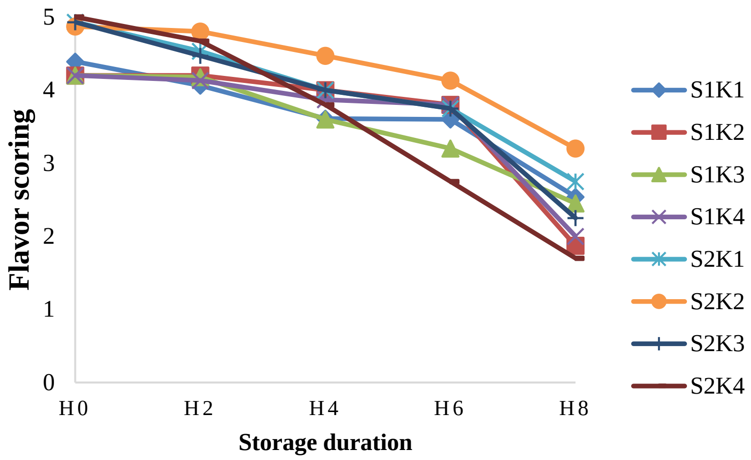


Figure 3. The appearance of Tasikmadu starfruit from day 0 (arrival of the fruit) until day- 8.

Fruit Taste Scoring

Based on the research result on starfruit taste scoring in different maturity stages and types of packaging treatment, it shows that the taste of starfruit was acceptable up to 4 DAH for all treatments. On the 4th day, all treatments crossed the limit value for fruit taste that can be accepted by consumers, namely at a value of 3.5 (Figure 3).



Description: H0: Day-1, H2: Day-2,.. H8: Day-8

Figure 4. Scoring of starfruit taste in different treatments of maturity stages and packaging type.

All treatments were able to maintain the fruit taste limit value at 6 HSP, except for treatment S1K3 and treatment S2K4. It was suspected that the S1K3 and S2K4 treatments were able to inhibit respiration in the fruit for longer, so the water content stayed the same, which caused the fruit to taste less sweet. The longer the fruit is stored, the less the quality. Furthermore, the large amount of water contained in the fruit can speed up the rotting process so that the taste of the fruit would become undesirable to consumers. Taste scoring was also conducted to assess the level of sweetness in starfruit that had been stored for eight days, in which all treatments failed to meet the acceptable limit.

Total Dissolve Solid (TDS)

The measure used to determine the sweetness level of starfruit is expressed in terms of Total Dissolved Solids content. The Total Dissolved Solids (TDS) could only be measured up to 6 HSP because, beyond that time, many of the starfruit had rotted or were not suitable for consumption. Based on the research results, the TDS content in Tasikmadu starfruit had significantly different results at 6 HSP and 8 HSP (Table 1).

The best result in TDS content at 6 DAH (the final limit for consumer acceptance) was S1K4 with a value of 9.66, while the lowest value was found in the cardboard packaging treatment (fruit sealed with newspaper) with a value of 8.22 (S1K1). These results showed that at maturity stage 4, the type of packaging treatment that can maintain the sugar content for longer in Tasikmadu starfruit was basket + newspaper + foam net (S1K4). The lowest value of TDS at maturity stage 4 was with cardboard + newspaper packaging (S1K1). This showed that the starfruit packaged in cardboard + newspaper (S1K1) experienced a high respiration rate, so a lot of sugar was used by the starfruit for the ripening process. Fruit ripening is a process where starch is wholly hydrolyzed into sucrose, which will cause the sugar content to be reduced as a substrate during respiration (Wiles *et al.*, 2000).

The highest value of TDS at maturity stage 5 was found in the basket treatment (fruit sealed with newspaper). These results showed that fruit that was ripe or at stage 5 of maturity was better if stored using a basket and covered with newspaper to maintain the sugar content in the fruit. This was thought to be because the use of baskets and newspapers can keep the fruit's respiration rate slower. However, the longer the fruit is stored, the longer it will experience weight loss and rot. The fruit would continue to experience respiration until rot occurs, so the TDS content in the fruit will decrease regardless. According to Kalsum *et al.* (2018) and Nascimento *et al.* (2000), during the fruit ripening process, starch degradation occurs in the fruit, and the results are converted into sugar components due to the activity of the enzymes α-amylase and β-amylase.

Table 1. TDS content of starfruit during storage

Stage	Packaging	DTS 0 (DAH)	2	4	6	8
S1	K1	9.66	8.88	8.66	8.22 b	7.77 b
	K2	10.22	9.77	9.22	8.66 ab	7.88 b
	K3	10.22	9.77	9.44	8.77 ab	7.77 b
	K4	10.44	10.10	9.77	9.66 a	9.11 a
S2	K1	11.55	10.22	9.66	8.99 b	7.44 b
	K2	11.44	10.44	10.21	9.99 ab	9.33 a
	K3	11.66	11.00	10.66	10.88 a	9.44 a
	K4	11.11	10.77	9.55	8.66 b	8.55 b

Notes: Numbers followed by the same letter in the same column are similar based on DMRT 5%.

Total Titratable Acidity (TTA)

The results of the analysis of variance on total titratable acidity (TTA) showed that the treatment of maturity stage and type of packaging was not significantly different after being stored from 0 HSP to 6 HSP (Table 2). This study indicates that the kind of packaging treatment during storage does not alter the internal quality of starfruit. This is likely because starfruit belongs to the category of non-climacteric fruits. The observation results indicate that the total titratable acidity values tend to decrease. This is consistent with the findings of Winarti et al., 2021, which show that during storage, metabolic activities such as respiration and transpiration occur, leading to the conversion of acids into sugars and thus reducing the acid content in the fruit.

Table 2. TTA content of starfruit during storage

Stage	Packaging	TTA 0 (DAH)	2	4	6
S1	K1	0.81	0.70	0.68	0.60 a
	K2	0.81	0.71	0.65	0.53 a
	K3	0.76	0.67	0.61	0.56 a
	K4	1.71	0.60	0.55	0.50 a
S2	K1	0.76	0.66	0.65	0.58 a
	K2	0.63	0.55	0.53	0.53 a
	K3	0.65	0.58	0.55	0.48 a
	K4	1.28	0.96	0.75	0.50 a

Notes: Numbers followed by the same letter in the same column are similar based on DMRT 5%.

4. Conclusions

The research results showed that starfruit could be accepted by consumers until the 6th day, with the best treatment in maturity stage 4 being basket packaging type (fruit sealed with newspaper and foam net). This treatment had good results, as indicated by the damage percentage value of 7.67%, taste score of above 3.5, TDS of 9.66, °*Hue* value of 99.89 with less bright colors, and TTA of 0.50.

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