Different Maturity Phases and Wrapping Material Types Affect Papaya Fruit's Quality (*Carica papaya* L.) *var*. Calina

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ABSTRACT

Background: Indonesia ranks fifth as a papaya producer. Indonesia's papaya production in 2023 will reach 1.239 million tons per year. Mechanical damage and disease attacks on papaya fruit can occur due to impacts during harvest and transportation. Harvesting fruit that is too young or not yet physiologically ripe will result in it not being fully ripe and the taste not being sweet enough, while harvesting fruit that is too ripe (overripe) will affect the papaya's shelf life, making it short and easily damaged. Damage by various factors, including 20-26% due to rot, 2-4% due to overcooking and 10% due to mechanical damage. This research aimed to determine the maturity phase and type of packaging material that effectively extends the shelf life of callina papaya fruit.

Methods: This study used a completely randomized design with two factors and all treatment combinations were repeated three times. The treatments used were the maturity phase and the type of packaging material: P0: no wrapping (control), P1: Newspaper, P2: Plastic Wrap: *LDPE (Low Density Polyethylene)* and P3: Polyethylene (PE) Net foam. Observation parameters include colour change, weight loss, fruit hardness level, Vitamin C content, TSS (Total Soluble solids), percentage of disease severity and intensity of disease attacks.

Result: The green maturity phase and plastic wrap were the best treatments to maintain the quality of papaya fruit.

Key words: *Carica papaya*, Maturity-phase, Shelf life, Wrapping.

INTRODUCTION

Indonesia is 5th in papaya production behind India, the Dominican Republic, Mexico and Brazil (Honoré *et al.*, 2019). Papaya production in Indonesia increased from 2022 to 2023, from 1.09 to 1.239 billion tons annually. The top 5 highest papaya producers in Indonesia are East Java (349,998 tons), Central Java (125,866 tons), East Nusa Tenggara (116,321 tons), West Java (110,751 tons) and Lampung (92,513 tons. The amount exported increased from 2022 to 2023, from 56.4 tons to 463 tons. However, the amount imported decreased from 0.101 tons to 0 tons. (FAOSTAT_data_en_4-18-2025, n.d.). Papaya fruit is classified as a climacteric fruit. One of the factors that causes the selling value of papaya fruit to fall is errors and damage that occur during harvest and post-harvest. Therefore, proper packaging is necessary. Packaging aims to wrap or protect products for distribution, storage, sale and use. Packaging has its importance in business because it allows products to be moved from the factory to customers and consumers. Packaging must maintain the product's safety, integrity and quality (Ojha *et al.*, 2015). The thin surface of the skin and tissue of the papaya fruit causes it to be easily damaged if it is scratched or hit. Mechanical impact can cause bruising on the surface of the skin and food tissue, triggering further damage due to the growth of microorganisms (Sigalingging *et al.*, 2019). Post-harvest disease in papaya fruit is anthracnose caused by *Colletotrichum gloeosporioides* Penz.Sacc. This disease is latent. The symptom is brown spots. This disease originates while still on the tree and develops after the fruit is fully ripe (Srikantharajah and Mikunthan, 2021).

Papaya has seven stages of fruit maturity, namely physiological ripe (mature Green), a tinge of yellow (color break), 25% yellow (quarter ripe), 50% yellow (half ripe), 75% yellow (ripe), 100% yellow (fully ripe) and too ripe (overripe). The appropriate harvest for local market demand is ripe papaya fruit with 95% green fruit, accompanied by a yellow tinge between the middle and tip of the papaya. The outer appearance of the fruit looks thick, but when cut open, the inside shows a yellowish-red colour (Kher and Sahu, 2018). Papaya fruit harvested at the MG (ripe Green) and QY (partially yellow) maturity levels experienced an

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average weight loss of 5.0% and 6.2% during storage. Weight loss is influenced by storage temperature; fruit that ripens at 25°C or is stored at 10, 12, or 15°C and then ripened, respectively, experiences a reduction in weight loss of 4.1%, 5.8%, 6.0% and 6.7% (Ali *et al.*, 2011).

Packaging functions to make food products easy and safe to transport, prevent contamination and prevent damage and changes in food ingredients (Morya and Sharma, 2020). Packaging can inhibit the increase of weight loss, total soluble solids and pH, as well as the decrease of firmness, total titratable acid, vitamin C and total mold and yeast. Based on the papaya characteristics, the best packaging method combines edible coating and wrapping active paper (Suwanti *et al.*, 2018). The research results (Arundathi *et al.*, 2019) show that a combination of newsprint and cardboard packaging materials is recommended for packaging papaya fruit. This is because the condition of the fruit in this packaging combination is better than that of packaging using wooden crates and bamboo baskets filled with banana leaves. Using transportation simulation at the frequencies of 1.5 Hz and 3 Hz, the plastic basket with newspaper filler was the best packaging to reduce quality degradation in papaya (Sigalingging *et al.*, 2019).

This study aimed to determine the effect of the maturity phase and the type of packaging on the quality of papaya fruit, storage time and reducing the intensity of disease attack.

MATERIALS AND METHODS

Place and time

This research was conducted from August to November 2024 at the Agronomy Laboratory of the University of Muhammadiyah Malang, Indonesia.

Research design

A completely randomized design with a factorial design was used in this research. The design used in this research was factorial and included two factors. The first factor was the fruit maturity phase (S), which consists of S1: Green, S2: Green-slightly yellow, S3: Yellowish Green. The second factor was the wrapping material (P), which consists of P0: no wrapping (control), P1: Newspaper, P2: low-density polyethylene (LDPE) Plastic Wrap and P3: Polyethylene (PE) Net foam. There were 12 treatment combinations and they were repeated three times.

Preparation of research materials

The calina variety of papaya fruit was obtained from farmers. The Papaya collected from the same farmer, location and plant age, with a uniform shape and size, was free from disease, had no defects, had a maturity phase according to research needs and was selected as a physiologically ripe fruit. Then, each one is wrapped according to the treatment and put into a fruit box with five papayas per box. Then, the fruit is transported by public transportation as far as 200 km and stored in a room. Observations were made during 21 days of storage.

Fruit colour change

Fruit skin colour was measured by visual observation using the fruit skin yellowness index. The degree of yellowness of the fruit skin is assessed with a score of 1 to 7, referring to the Cavendish banana score but adjusted to the condition of the papaya. These values were: 1= Green, 2 = Green with a little yellow, 3= Yellowish green, 4 = More yellow than green, 5= Yellow with green tips, 6= Full yellow, 7= Yellow with a few brown spots (overripe) (Soltani *et al.*, 2010).

Fruit weight loss

Weight loss measurements are carried out gravimetrically. For weight loss, fruit was weighed before treatment (A) and after storage (B) and the weight loss was calculated as:

$$\frac{A/B}{A} \times 100\%$$

Where,
a: Initial weight.
b: Final weight (Sukorini *et al.*, 2013).

Fruit hardness

The fruit's firmness or hardness was tested using a Hardness Tester and observations were made every four days for 21 days of storage using a Penetrometer. Fruit firmness was measured at four points of the equatorial region using a firmness tester. Pulp firmness was measured using an (N.O.W., FHR-5) with a 5 mm cylindrical probe. Firmness was defined as the maximum force (N) required until tissue failure (Sukorini *et al.*, 2013).

Vitamin C content

Vitamin C content was titrated using iodine and 3-4 drops of starch solution indicator with a concentration of 1 g/100 ml. Vitamin C content was measured by crushing 25 g of fruit flesh, then filtering by adding distilled water and putting it into a 100 ml measuring flask; take 25 ml of the solution and give 3-4 drops of starch solution indicator, then titrating with iodine. Titration is carried out until a stable dark blue colour is formed. Referring to Hernández *et al.* (2006), Vitamin C content is calculated using the equation:

Vitamin C (mg/100 mg of material) =

ml Iodine 0.01 N × 0.88 × fp × 100 Sample weight (g)

Where,
N = Normality of iodine solution (0.01 N).
Fp = Dilution factor (100 ml/25 ml), 1 mg iodine 0.01 N=0.88 mg ascorbic acid.

Total soluble solids (TSS)

TSS was observed using a Refractometer N1-E, Atago Co., Tokyo, Japan. Samples of papaya fruit were taken from three parts: the tip, middle and bottom. The mashed samples were then placed on the surface of the

refractometer glass to see the sugar content value. Observations were made from the beginning of storage and the end of the research (Sukorini *et al.*, 2013).

Intensity of disease attacks

The intensity of disease attacks on the fruit was observed 3 days after storage until the research was completed. Measurements are expressed:

$$I = \frac{n}{N} \times 100$$

Where,
I = Intensity of disease attack.
n = Number of fruits attacked by disease.
N = Number of fruits observed (Sukorini *et al.*, 2013).

Statistical analysis

All data obtained were analyzed by analysis of variance (ANOVA) with a statistical significance value of $p<0.05$. If a significant effect exists, the data is tested for differences with Tukey's HSD.

RESULTS AND DISCUSSION

In this study, there was no interaction between the maturity phase treatment and the type of papaya packaging material on all research variables at all observation ages.

Weight loss and colour change

The maturity phase had a very significant effect, while the packaging material had a significant effect on weight loss. The green maturity phase treatments, plastic wrap packaging material and newspaper showed the slowest colour change compared to the other treatments (Fig 1). The same results also occurred in fruit weight loss (Fig 2). The smallest fruit weight loss was in the green maturity phase, fruit wrapping in newspaper and plastic wrap.

Vitamin C content

The maturity phase had a very significant effect on vitamin C content, while the packaging material had no significant effect. Up to 12 days after treatment, vitamin C increased in all treatments except the control treatment. However, after that, the vitamin C content in all treatments decreased (Fig 3).

Total soluble solids

The maturity phase and packaging materials did not significantly affect total soluble solids. Total soluble solids continued to decrease from observation 4 days to 20 days after treatment, except for the green maturity phase treatment and the type of net foam wrapping. Only fruit wrapped in plastic wrap had total soluble solids that increased at the end of observation/20 days after treatment (Fig 4).

Fruit hardness level and intensity of disease attacks

The maturity phase had a very significant effect, while the packaging material had no significant effect on the Hardness level and intensity of disease attack. The green maturity phase shows the hardest fruit hardness, indicated by the significant hardness value of the fruit. All treated fruits were able to survive well only up to 16 days after treatment, except for the newspaper wrapping treatment, which lasted up to 16 days. Likewise, plastic wrap also showed the hardest fruit hardness and was even able to survive up to 20 days after treatment (Fig 5). Regarding disease incidence, only the green maturity phase treatment survived up to 9 days of storage, while the others had more than 50% disease attack rates (Fig 6).

The research showed that the best treatments were the green maturity phase treatment and the plastic wrap packaging material. Several observation parameter results support this. These parameters include the level of colour change, weight loss, fruit hardness, vitamin C and the

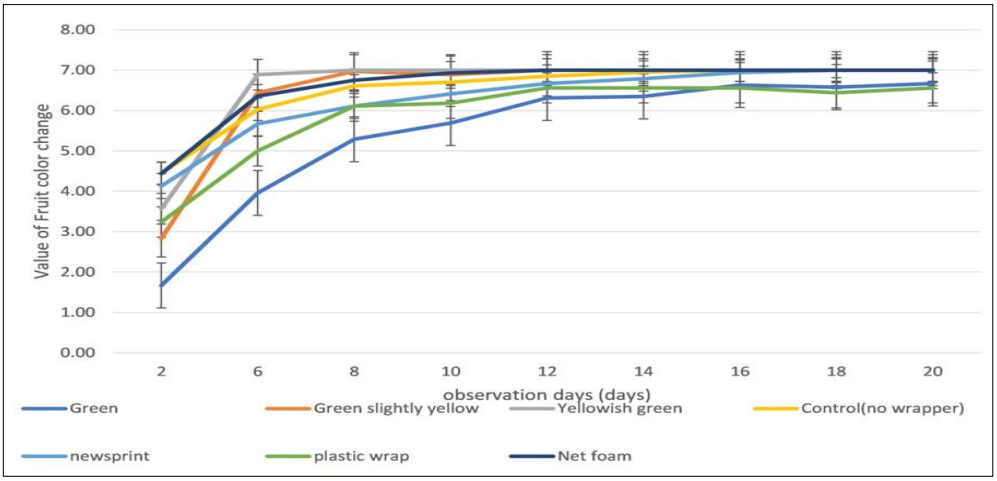


Fig 1: Average value of papaya fruit colour change due to ripeness phase treatment [Green, green slightly yellow, yellowish green, Control (no wrapping)] and type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) in observations 2 to 20 days after treatment. Storage at 26°C.

intensity of disease attacks on the fruit. Papaya fruit is climacteric. The quality of climacteric fruit depends on the timeliness of harvest and how it is stored (Arundathi *et al.*, 2019). This result aligns with (Joshi *et al.*, 2023). Mangoes harvested at TSS 7-9°brix showed good nutritional content compared with 9-11°brix.

Fruit has the potential to be stored for a long time when it is still green but physiologically ripe. The treatment of plastic wrap packaging material was shown to inhibit the colour change of papaya fruit for up to 20 days (the day after treatment) to become 100% full yellow colour. This is because this treatment can inhibit the respiration and transpiration processes and the plastic wrap packaging material can maintain the colour of the papaya fruit during storage. According to (Fabi and do Prado, 2019), using a modified atmosphere with polyethylene plastic wrapping can extend the shelf life of tomatoes for 6 weeks. According to (Nur Sakinah *et al.*, 2020), polyethylene (PE) packaging is suitable for use in controlled air storage systems because the permeability of PE film to CO_2 gas is more significant than O_2. Hence, the rate of accumulation of CO_2 gas around the material is lower than the absorption of O_2. This is also in line with research that showed significant interaction effects between maturity stage, spermina, calcium lactate and packaging materials on all observation parameters of this study. The minimum physiological weight loss was at twenty-five per cent maturity, treatment dipped in spermina (2.0 mm) with shrink packaging. The organoleptic quality was still good and the maximum shelf life was 16 days (Patil *et al.*, 2018).

A common change during fruit storage is the loss of green colour. This is caused by chlorophyll degradation.

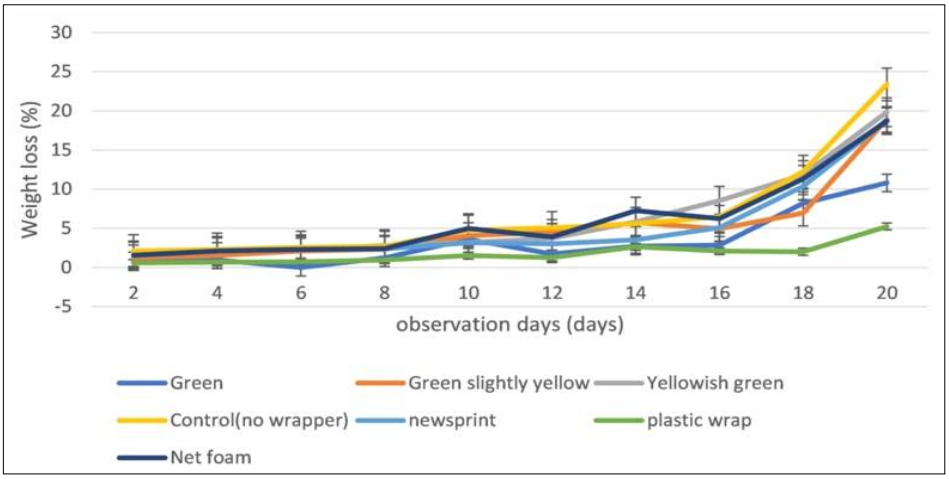


Fig 2: Average percentage of weight loss of papaya fruit due to ripeness phase treatment [Green, green slightly yellow, yellowish green, control (no wrapping)] and type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) in observations 2 to with 20 days after treatment, Storage at 26°C.

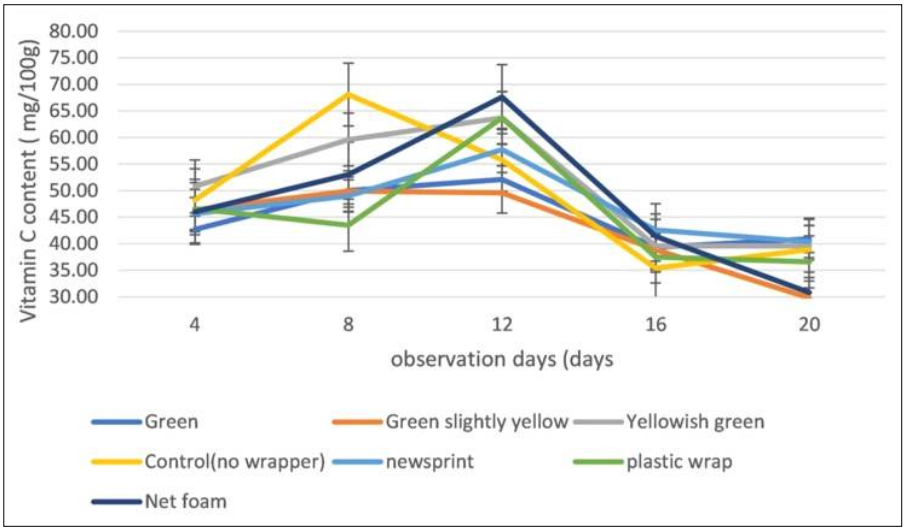


Fig 3: Average Vitamin C content of papaya fruit due to ripeness phase treatment [Green, green slightly yellow, yellowish green, control (no wrapping)] and type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) at observations 4 to 20 days after treatment. Storage at 26°C.

During storage, the fruit's chlorophyllase carries out activities that cause the loss of chlorophyll (Kuai, Chen and Hörtensteiner, 2018). The factors responsible for chlorophyll degradation are changes in pH, the oxidative system and the *Chlorophyllase enzyme*. During the storage period, papaya fruit experiences a decrease in fruit weight. The treatment of plastic wrap packaging material is thought to be able to withstand the processes of respiration and transpiration (water loss) during storage (Ibrahim *et al.*, 2022). Packaging aims to prevent weight loss, improve product image, avoid or reduce damage during transportation and act as a promotional tool. Agricultural products harvested are living structures; therefore, they still carry out metabolic activities. These metabolic activities include the respiration process, namely the oxidative breakdown process of complex fruits such as starch, sugar and organic acids in cells into small molecules of CO_2, H_2O and energy used by the cells themselves and the process of transpiration (water evaporation), the magnitude of the respiration rate is a guide or indication of the speed of compositional changes in the fruit.

Vitamin C levels increased initially and then decreased during storage. This is caused by the fruit undergoing a ripening process at the beginning of storage (Yamdeu Galani *et al.*, 2017). The results of their research also show that the vitamin C content increases during cooking.

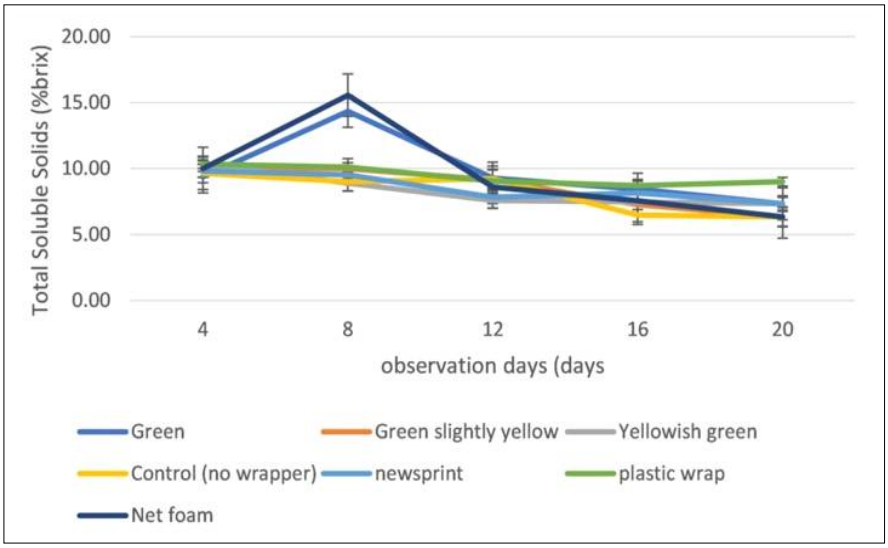


Fig 4: Average total soluble solid of papaya fruit due to ripeness phase treatment [Green, green slightly yellow, yellowish green, control (no wrapping)] and type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) at observations 4 to 20 days after treatment. Storage at 26°C.

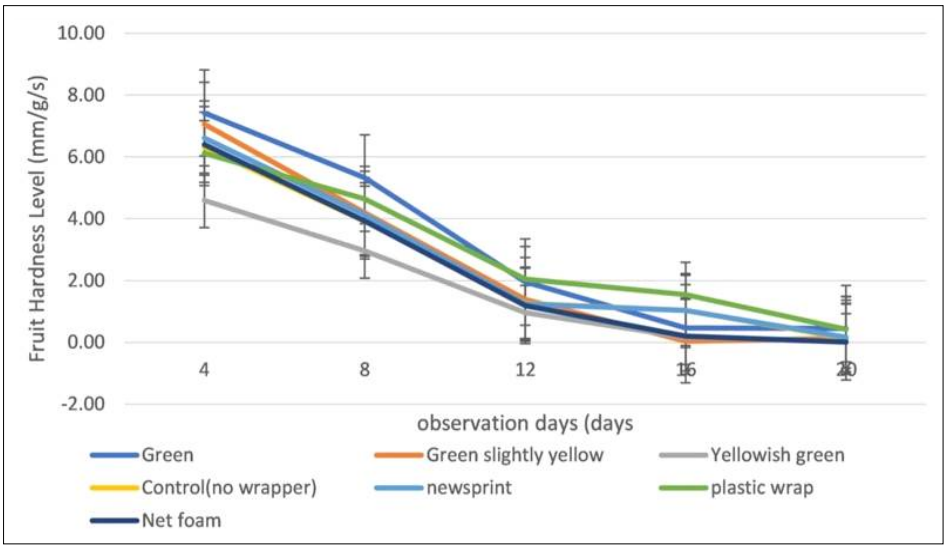


Fig 5: Average fruit hardness of papaya fruit due to ripeness phase treatment [Green, green-slightly yellow, yellowish green, control (no wrapping)] and type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) in observations 4 to 20 days after treatment. Storage at 26°C.

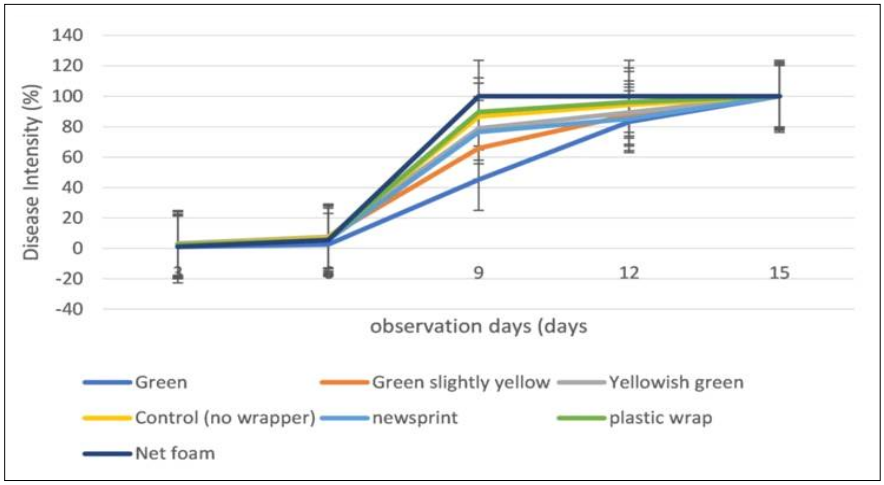


Fig 6: Average intensity of papaya disease attacks due to the maturity phase treatment [Green, green-slightly yellow, yellowish green, control (no wrapping)] and the type of fruit wrapping material (newspaper, low-density polyethylene (LDPE) plastic wrap, PE net foam) in observations 4 to 15 days after treatment. Storage at 26°C.

Total carotene increased with increasing maturity and reached a maximum value 2-4 days after the fruit was fully ripe. Decreased levels of vitamin C are caused by fruit that is overripe (rotten) being attacked by disease. The research results stated that the vitamin C content in the early stages of maturity increases and then decreases in stored fruit until it approaches rotten. Based on this, scale 6 is very susceptible to rotten conditions that have excess water content, so vitamin C content is very easily lost (Yungyuen *et al.*, 2021).

The total soluble solids content of papaya fruit after the day of observation showed an increase and after that, the total solids value decreased. This is because, during the fruit ripening process, the hydrolysis process of starch into sugar occurs, resulting in the TSS content of the fruit increasing gradually after harvest during the ripening process (Rooban *et al.*, 2016). The total soluble solids content of fruit flesh increases with the expansion of the yellow color on the surface to a level of 80%, after which it decreases with the expansion of the skin color due to the hydrolysis of sugar into organic acids which is used for the respiration process (Suketi *et al.*, 2016).

The observations showed that the papaya fruit's hardness level decreased during storage at room temperature. The decrease in hardness in calina papaya fruit is due to the ripening process. This decrease in hardness value occurs due to the degradation of water-insoluble pectin (protopectin) and its transformation into water-soluble pectin. This decreases the cohesive power of the cell walls, which bind one cell wall to another (Sigalingging *et al.*, 2019).

The intensity of disease attacks also accompanies the decrease in fruit hardness. In treating the green maturity phase and plastic wrap, the lowest disease attack intensity was up to 12 days. This is because in the green maturity phase, it was still not fully ripe and the fruit's flesh was still hard. Hence, the anthracnose disease spreads more slowly than on ripe fruit. At the same time, the treatment of the wrapping material, Plastic wrap, can inhibit respiration and ethylene so that the fruit remains fresh and can suppress disease infections. The smallest percentage of disease attacks was shown in the green maturity phase treatment up to 18 days after planting, with a value of 60%.

CONCLUSION

There was no significant interaction between the maturity phase treatment and wrapping material. Based on the overall study, it can be inferred that papaya should be harvested at green maturity to increase shelf life and improve its quality. The best wrapping material was PE plastic wrap. The treatment of green maturity and PE plastic wrap resulted in minimum physiological loss in fruit weight and firmness and an increased intensity of disease attack.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from using this content.

Informed consent

We did not use animals for this research.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the study's design, data collection, analysis, publication decision, or manuscript preparation.

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