Article

Changes in the Quality of Golek Mango (*Mangifera indica L.*) with Hot Water Treatment Stored at Room Temperature, Zero Energy Cool Chamber and Refrigerator

Muh Arfan[1], and Giovanni Tri Hadi Wibowo Budiardjo[2]

[1] Research Group for Postharvest Technology and Biotechnology, Makassar, Indonesia
[2] Department of Industrial and Systems Engineering, Chung Yuan Christian University, 320314, Taiwan, Republic of China

Abstract

Mango is a tropical fruit that has become a popular fruit for the community. High production of mango requires proper treatments for handling, storage, and other postharvest treatments which are still lacking. These mangoes have a major postharvest handling problem because mangoes are easily damaged, which makes their shelf life relatively short. One treatment such as cold storage of fruits can be done to maintain the quality of mangoes in accordance with market requirements and demands. The purpose of this study was to determine the changes in Golek mangoes and to determine their shelf life after hot water treatment stored in the room temperature, zero energy cool chamber, and refrigerator. The method of this study consisted of two stages, namely the first stage of research observing the quality of mangoes and hot water treatment. The second stage of research was the application after stored in the zero-energy cool chamber & analyzing their quality of mangoes after storage in the form of testing for shrinkage weight & hardness. The results obtained in this study were the quality of mangoes before storage in ZECC: Weight loss %, hardness level 62.63 N, vitamin C 2.38%, total acid 1.9%, & total dissolved solids 3.4 Brix%.

Article History
Received June 3, 2025
Accepted November 9, 2025
Published November 18, 2025

Keywords
Fruit, Storage conditions, Post-harvest treatment

1. Introduction

Cold storage of fruit is one of the treatments that can be attempted to maintain the quality of mangoes according to the wishes and demands of the market. During storage, mango fruit still undergoes respiration and transpiration processes, so changes in its internal and external quality still occur (1). Cold storage of fruit is one method of postharvest handling of fruits, such as storage in a refrigerator. Still, this method is usually constrained by the need for electrical power, which is difficult to apply in central fruit-producing villages so storage without electricity is needed (2). One of the cold storage technologies that can be applied after harvest or post-harvest that is environmentally friendly and inexpensive is storage using ZECC (3).

A Zero-energy Cool Chamber (ZECC) is usually called an eco-friendly and cheap storage system because a fruit storage system does not require electrical energy. The inside of the Zero-energy Cool Chamber has a low temperature and high relative humidity (4). In addition to its environmentally friendly and cheap use because it does not require electrical energy, ZECC also only requires bricks, sand, water, and a plastic roof to make the ZECC storage

* Correspondence : **Muh Arfan** muharfan446@gmail.com

system. These materials can provide good temperature and humidity for fruit storage (5). Temperature and relative humidity (RH) in the storage room are important environmental factors that affect the fruit ripening process and final quality (4).

Research on storage with the Zero Energy Cool Chamber method has been carried out by several researchers, including Firdaus in 2021 who examined the combination of ZECC storage technology with pre-handling treatment on the quality of mango fruit. Singgang in 2021 examined the combination of ZECC storage with packaging treatment, Dirpan in 2018 examined the quality of mango fruit stored in ZECC, and Mishra in 2020 examined the storage of vegetables in ZECC. However, research using the ZECC storage method with hot water treatment is still lacking (6). Therefore, a study was conducted with the title "Changes in the Quality of Mango Fruit (*Mangifera Indica L.*) with Hot Water Treatment in Zero Energy Cool Chamber Storage.

2. Materials and Methods

The tools and instruments used in this research are a Zero Energy Cool Chamber (ZECC), fruit rack, temperature and RH sensors, moisture analyzer, penetrometer, digital hand refractometer, hose, scales, analytical scales, pH meter, stirring rod, beaker, Erlenmeyer flask, horn spoon, volumetric pipette, spoon, water bath container knife blender coarse cloth and fine cloth. The materials used in this study are aluminum foil distilled water detergent mango PP indicator NaOH iodine pH 7 buffer alcohol cotton and labels. The criteria for mangoes used in this study are the fruit's maturity level (which has not reached perfect maturity) with the Golek mango variant obtained from the same tree without damage to the fruit and color index at level 2 (light green).

2.1. Research Procedures

2.1.1. Stage one

The first stage of research is the observation of the physical quality of mango fruit and hot water treatment. Hot water treatment (A) consists of 4 levels, namely:

A = Without treatment (control)
A1 = Soaking temperature 35 ±10°C
A2 = Soaking temperature 47 ± 10°C
A3 = Soaking temperature 52 ±10°C

The treatment of soaking time (B) consists of 4 treatment levels, namely:

B = Without treatment (control)
B1 = Soaking time of 5 minutes
B2 = Soaking time of 10 minutes
B3 = Soaking time of 15 minutes

After treatment of the sample, it was stored at room temperature and observed periodically, namely every 2 days until the sample was damaged.

2.1.2. Stage two

The second stage of research is the application of the best treatment in the refrigerator, room temperature, and zero-energy cool chamber and testing the quality of mango fruit during storage in terms of weight loss, hardness, vitamin C, total acid, and total soluble solids.

2.1.2.1. Weight loss

Weight loss can be determined by weighing the sample. Mango samples before and after storage were weighed using an analytical balance and calculated using the formula to determine the weight loss of mango fruit during storage. Weight loss is calculated using the following formula (7):

$$W(\%) = \frac{(mi - mt)}{mi} \times 100\% \tag{1}$$

Description:
W= Weight loss (%)
mi= Initial mass (gr)
mi= Final mass (gr)

2.1.2.2. Hardness level

The indicator of fruit hardness level can be done using a penetrometer tool with a maximum load of 150 grams. Press on the tip, center, and base of the fruit for 10 seconds, then continue pressing until it reaches the fruit's skin and enters the pulp. The tool sensor will show a sign indicating it has reached its depth. The result displayed on the tool is the hardness value of the fruit, measured in millimeters of penetrometer needle depth (8).

2.1.2.3. Vitamin C

Determination of vitamin C levels can be done using UV-VIS spectrophotometry. The mango fruit was peeled, washed, cut into small pieces, and put into a blender. Furthermore, the mango fruit that had been blended was filtered using filter paper, and 2 ml was taken. The mango filtrate was put into a 50 ml volumetric flask and then added distilled water until the limit mark then homogenized and measured the absorbance (9).

2.1.2.4. Total acid

A sample of 10 grams was added to 100 ml of distilled water and then homogenized using a blender. The filtrate was filtered with filter paper, after which 20 ml was taken and given three drops of phenolphthalein (pp) indicator. The sample filtrate was titrated using 1 N NaOH until the color was changed to a stable orange color. The total acid was calculated using the following formula (1):

$$\text{Total Acid } = \frac{ml\ NaOH \times N \times Fp \times Mr\ NaOH}{weight\ of\ sample} \times 100\% \tag{2}$$

Description:
Ml NaOH = Volume of NaOH used during titration
N = Normality of NaOH (0.1 N)
Fp = Dilution or dilution factor
Mr NaOH = Molar mass of NaOH

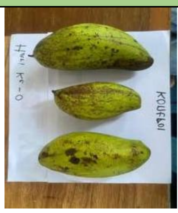
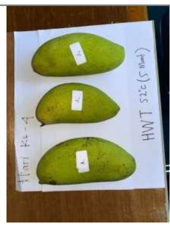
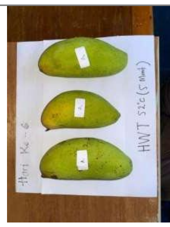
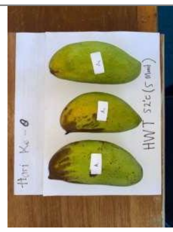
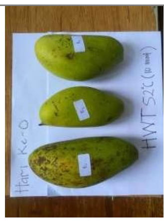
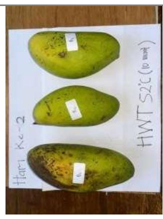
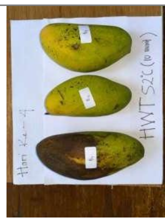
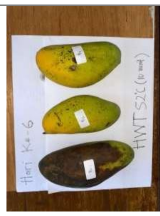
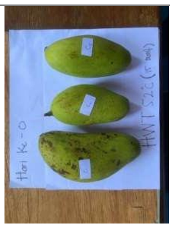
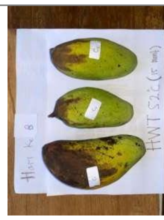
2.1.2.5. Total Dissolved Solids

Total dissolved solids can be measured using a digital refractometer. The value of total soluble solids was done by taking a sample of mango fruit in the form of juice from the base and tip of the fruit and then measuring it using a digital refractometer. This was done by dripping mango fruit juice on the prism of a digital refractometer, and the measurement results of total soluble solids would be automatically read by the tool. The TPT value is determined by looking at the number on the tool with units of Brix (10).

3. Results and Discussion

The results of mango fruit storage from preliminary research on "Changes in the Quality of Golek Mango Fruit (*Mangifera Indica L.*) with Hot Water Treatment at Room Temperature Storage, Zero Energy Cool Chamber & Refrigerator," which is carried out by giving hot water treatment to mango fruit and then storing it at room temperature until the mango fruit decays, indicate that the storage of mango fruit has ended to obtain the best results or treatments that will be applied to the three types of storage. The results of visual changes in mango fruit during preliminary storage can be seen in the table 1.

Table 1. Visual Deterioration of Physical Quality of Mango Fruit during Storage.

Sample	Storage Duration				
	Day 0	Day 2	Day 4	Day 6	Day 8
Control					
Temperature 52^{0}C (5 Minutes)					
Temperature 52^{0}C (10 Minutes)					
Temperature 52^{0}C (15 Minutes)					

The results obtained from preliminary research based on visual mango fruit showed that the mango fruit without treatment (control) had the lowest physical quality because the mango fruit on day 4 began to rot, and there were changes in texture and blackened skin color. On days 6 and 8, physical quality damage was increasingly evident, and the mango fruit was overgrown with microorganisms. Mango fruit treated with hot water treatment at a temperature of 52°C for 5 minutes showed that changes in the color of the mango fruit skin occurred on day 8; the upper fruit skin around the stalk of the mango fruit became brownish. Mango fruit given hot water treatment at a temperature of 52°C for 10 minutes showed that overall, mango fruit skin became yellowish green on day 4 and day 6. On day 8, the mango fruit's skin is browned on the stalk and at the center of its skin. Mango fruits treated with hot water treatment at a temperature of 52°C for 15 minutes showed that on day 6 there was a change in the skin of the fruit to yellowish green and on day 8, the overall skin of the mango fruit experienced a brownish color change at the top of the fruit stalk. In addition to visual observations on mango fruit, weight loss observations were also made during storage. The results of the observations of the weight loss of mango fruit during storage can be seen in Figure 1.

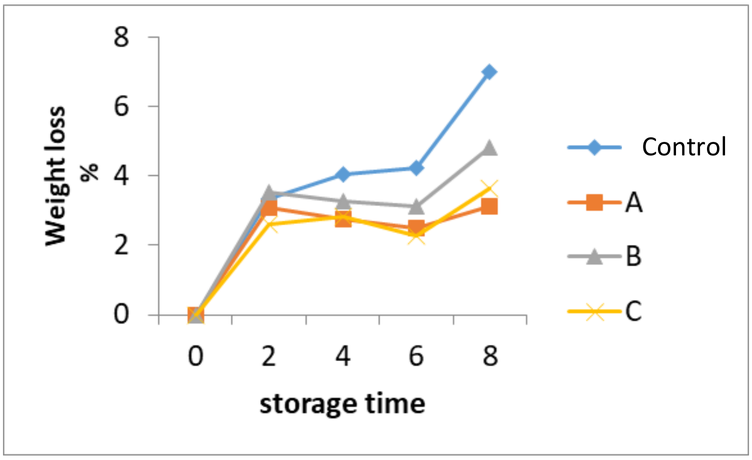


Figure 1. Relationship between HWT temperature and soaking time on weight loss of mango fruit in the preliminary study.

The results of weight loss obtained during mango fruit storage based on the figure above showed that mango fruit storage without any treatment obtained a high weight loss value, while the treatment with the lowest value was treatment a (52°C for 5 minutes) and treatment C (52°C for 15 minutes), with a difference in weight loss of only .02%. The determination of the best treatment also refers to several studies conducted by (11). Based on the description above, the best treatment for mango fruit with hot water treatment is obtained at 52°C for 15 minutes.

3.1. Weight loss

Weight loss occurs due to metabolic processes in the fruit, namely respiration and transpiration during the storage process until fruit ripening which can remove water and other organic materials (11). The results of the analysis of variance showed that the type of storage (sig. .000), as well as the interaction between the type of storage and length of storage (sig. .000), showed that the results obtained significantly influenced at the 5% level ($p \leq .05$) on the weight loss of mango fruit during storage so that further Duncan's test was conducted. The results of Duncan's further test for the type of storage showed that the type of storage at room temperature had the highest weight loss and was significantly different from the type of storage in the refrigerator, as well as storage in ZECC.

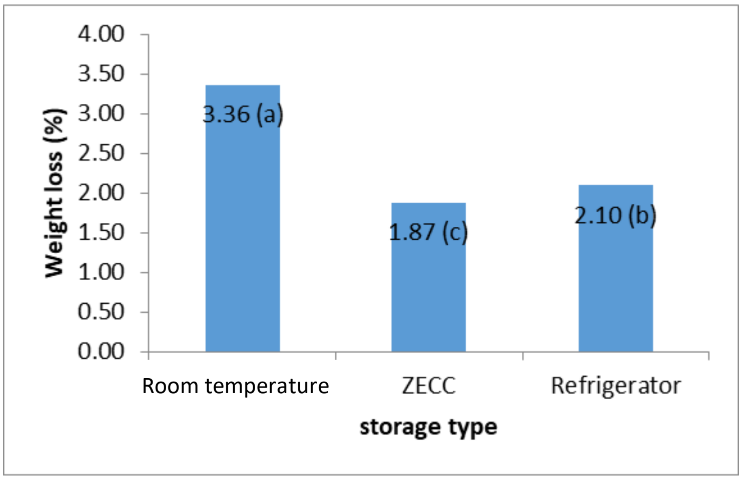


Figure 2. The relationship between storage type and weight shrinkage of mango fruit; values followed by different letters indicate significantly different results ($p<.05$).

Weight loss in mango fruit with various types of storage can be seen in Figure 2, which shows that storage at room temperature has the highest percentage of weight loss. Mango fruits stored at room temperature experienced a weight loss of about 3.36% due to higher respiration and transpiration processes compared to storage in the Zero Energy Cool Chamber (ZECC) and refrigerator. Storage in ZECC showed the smallest percentage weight loss of 1.87%, as high air humidity inhibited respiration and water loss (2). Refrigerators have an average weight loss of 2.10% and can extend the shelf life of fruit by reducing the rate of respiration and activity of microorganisms (12). Research conducted by (13) states that room temperature can cause faster shrinkage of fruit weight due to sharp metabolic activity during storage.

The relationship between the type of storage and length of storage for mango fruit on weight loss parameters can be seen in Figure 3. Weight loss of mango fruit on different storage types and storage durations can be seen in (Figure 3). Weight loss of mango fruit at room temperature storage based on the graph above shows that the value increases with the length of storage up to 9 days. Weight loss in ZECC storage, based on the graph above, shows that there is a decrease in weight loss with a storage period of up to 15 days. This shows that the weight loss of mango fruit during storage is caused by the evaporation of water from the fruit tissue through the stomata or fruit skin. According to recent research, the respiration process can result in carbon loss contained in mango fruit sugar, which reacts with oxygen to produce simple volatile compounds, namely carbon dioxide and water vapor, so that the fruit loses its weight (14). In refrigerator storage, the weight loss value based on the graph shows a fluctuating value and tends to increase with a shelf life of up to 21 days. This occurs because the low temperature of refrigerators can suppress rapid respiration and transpiration processes so that the shelf life of mango fruit can be extended. (15).

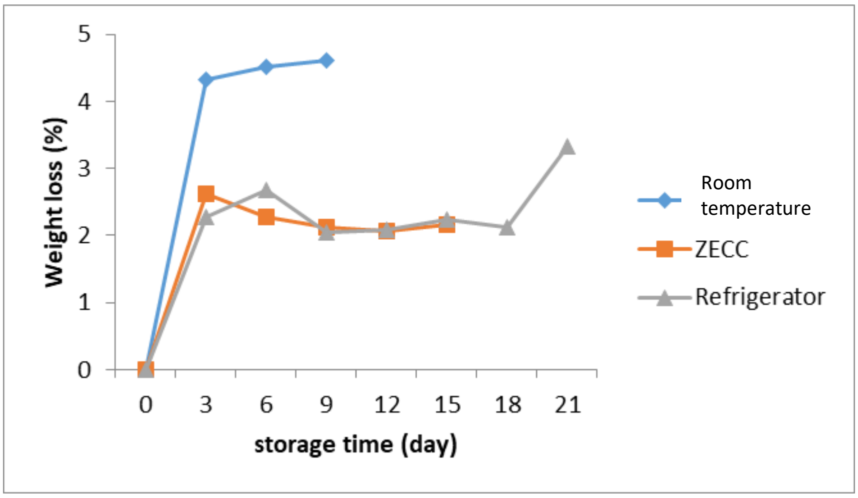


Figure 3. Relationship between storage type and storage duration on weight loss of mango fruit.

3.2. Hardness level

The level of fruit hardness is also related to the weight loss that occurs in the fruit. Excessive weight loss will cause a decrease in the level of fruit hardness, and the fruit skin will also experience shrinkage, resulting in decreased freshness of the fruit (16). The results of the analysis of variance showed that the type of storage (sig. .000) and the interaction between the type of storage and the length of storage (sig. .000) had a significant effect at the 5% level ($p \leq .05$) on the level of hardness of mango fruit during storage, which led to further testing using Duncan's test. Duncan's further test results for the type of storage showed that all types were significantly different, with refrigerator storage having the highest hardness levels compared to ZECC storage and room temperature storage.

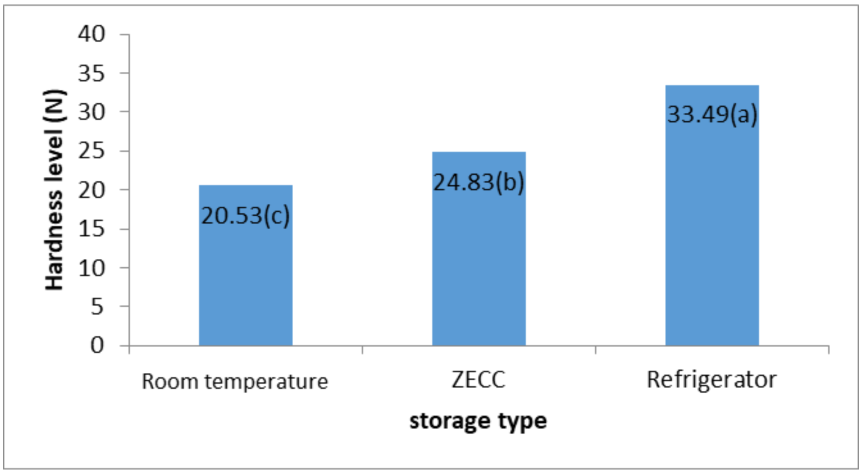


Figure 4. Relationship between storage type and the level of hardness of mango fruit; values followed by different letters indicate significantly different results ($p < .05$).

The hardness of mango fruit at various types of storage is shown in Figure 4. Storage at room temperature has the lowest hardness level (20.525 N) and is significantly different from other storage. The refrigerator had the highest hardness (33.485 N), while ZECC had a hardness of 24.833 N. The decrease in hardness is due to differences in humidity and temperature which affect the respiration and transpiration processes. Low humidity and high temperature accelerate water evaporation and respiration, causing faster softening (17). In ZECC storage, high humidity inhibits water evaporation and slows down softening of the pulp. Controlled ZECC temperature maintains fruit firmness (14). Meanwhile, storage in a refrigerator maintains fruit firmness (33.485 N) by controlling temperature and humidity, reducing respiration. However, abnormal ripening in the refrigerator can cause softening of fruit texture and cell damage (12). The relationship between the type of storage and the length of storage of mango fruit on the hardness parameter can be seen in Figure 5.

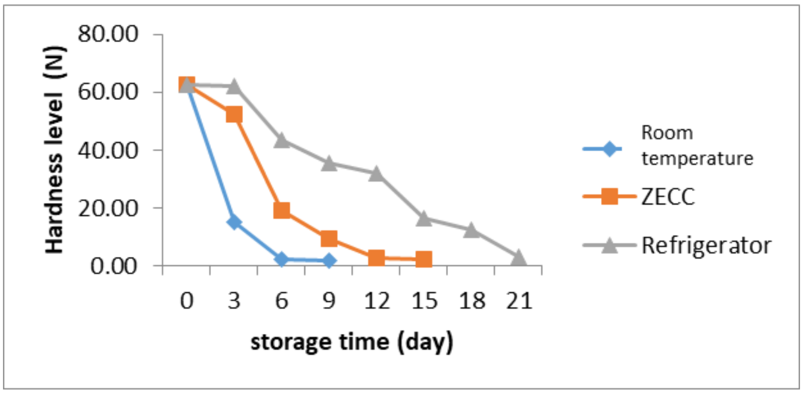


Figure 5. Relationship between storage type and storage duration on the firmness of mango fruit.

The hardness level of mango fruit in different storage types and storage duration can be seen in Figure 5. The hardness level at room temperature storage based on the graph above shows that the hardness level value decreases with the length of storage until day 9. The hardness level of mango fruit with refrigerator storage shows a decrease in hardness level with the length of storage up to 21 days. According to Utama et al. (2012), room temperature can cause a faster respiration process compared to cold temperature storage, so mango fruits stored at room temperature experience a drastic decrease in hardness value compared to mango fruits stored at cold temperatures.

The hardness level of mango fruit in ZECC storage showed a decrease in hardness value with the length of storage up to 15 days. This occurs because the polysaccharides in mango fruit are increasingly decomposed, making the fruit softer, and leading to the breakdown of cell wall compounds. The initially insoluble protopectin turns into soluble pectin during the respiration process in ripening mango fruit (18). Recent research also supports these findings. Dirpan et al. (2017) found that storage at ZECC can maintain fruit firmness better than room temperature, as high humidity reduces the rate of water evaporation and respiration (2). In addition, Tefera et al. (202) showed that storage in the refrigerator helps maintain fruit firmness by reducing fruit respiration and metabolic activities (12). Kusumiyati et al. (2018) also noted that room temperature accelerates fruit softening due to increased enzymatic activity and cell wall breakdown (17). Islam et al. (2019) added that this change in firmness is related to the degradation of cell wall components, such as protopectin to pectin, leading to softening of fruit texture (14).

3.3. Vitamin C

Acidic properties can affect the vitamin content in fruits and vegetables. The higher the vitamin C content in fruits and vegetables, the stronger the sour taste that will be produced. (19). The results of the analysis of variance showed that the type of storage (sig. .000) and the interaction between the type of storage and the length of storage (sig. .000) had a significant effect at a 5% level ($p \leq .05$) on vitamin C of mango fruit during storage, so further Duncan's test was carried out. Duncan's further test results for the type of storage showed that room temperature storage had the highest vitamin C value, which was significantly different from ZECC and refrigerator storage.

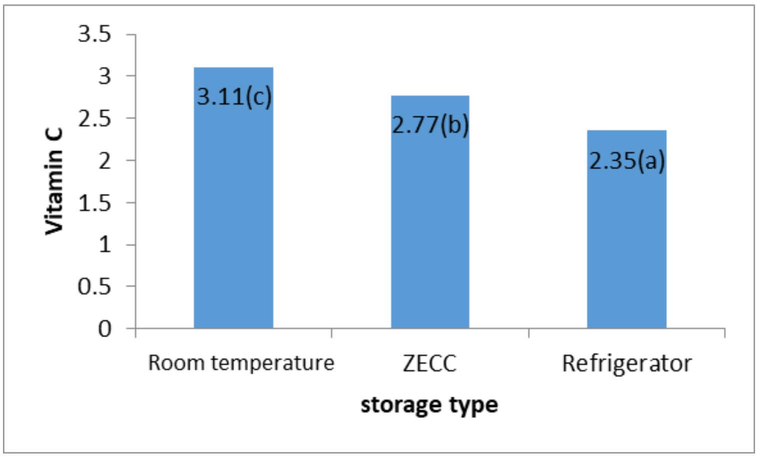


Figure. 6. Relationship between storage type and Vitamin C of mango fruit; values followed by different letters indicate significantly different results ($p < .05$).

Vitamin C in mango fruit stored in 3 types of storage can be seen in Figure 6, which shows that refrigerator storage has the lowest vitamin C content during storage of mango fruit at only 2.353%. The highest vitamin C content during storage is at room temperature, with vitamin C at 3.107%, and at ZECC with vitamin C at 2.77%, which is only .33% lower than the highest vitamin C content. Vitamin C content can be influenced by the temperature and length of fruit storage because it affects the respiration and transpiration processes in fruit ripening. In addition, mango fruit storage is also influenced by the level of fruit maturity. According to (20), there is an increase in vitamin C content from ripe mango fruit to ripe mango fruit due to the process of fruit development, namely, the synthesis of vitamin C also increases due to the presence of the enzyme L-gluconolactone oxidase in the fruit.

The relationship between the type of storage and the length of storage of mango fruit against vitamin C parameters can be seen in Figure 7. The Vitamin C content of mango fruit, stored under different conditions for varying durations, can be observed in Figure 7. The graph depicting the storage of mango fruit at room temperature shows an increase in Vitamin C levels and storage duration up to 9 days. In ZECC storage, the levels of Vitamin C also increase during the storage period, up to 15 days. The rise in Vitamin C levels from ripening to ripe mango fruit is attributed to the fruit's developmental process. According to (20), it was stated that during development, there is an increase in Vitamin C synthesis due to the presence of the enzyme L-gluconolactone oxidase in the fruit. When stored in a refrigerator, the levels of Vitamin C fluctuate during prolonged storage periods of up to 21 days. In climatic fruits like mangoes, the levels of Vitamin C generally increase as total soluble solids in the fruit increase. The content will reach its peak upon optimum ripeness but will then decrease as withering or decay sets in. However, when stored in a refrigerator, fluctuations were observed possibly due to oxidation influenced by factors such as heating, light exposure, and catalysts during testing pauses (10).

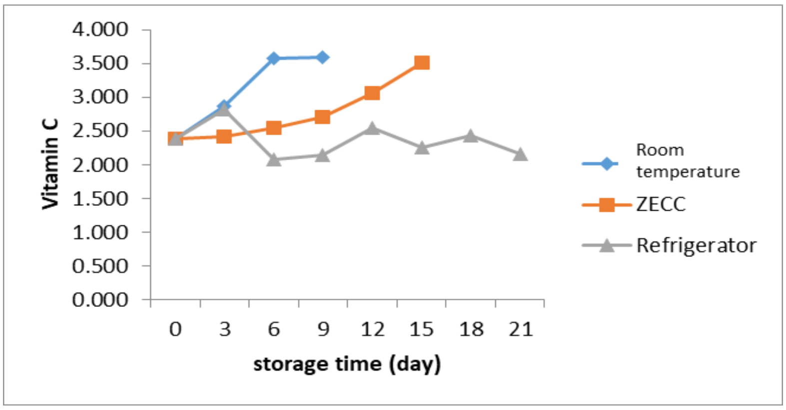


Figure 7. Relationship between storage type and storage duration on vitamin C of mango fruit.

3.4. Total Acid

The increase in acidity in food ingredients can occur due to the decomposition of glucose into acids (1). The results of the analysis of variance showed that the type of storage (sig. .000) and the interaction between the type of storage and storage duration (sig. .000) indicated that the results obtained had a significant effect at the 5% level (p≤.05) on the total acid of mango fruit during storage, so further Duncan's test was carried out. Duncan's further test results for the type of storage showed that storage in the refrigerator had a higher value than room temperature storage and ZECC, and all three types of storage were significantly different.

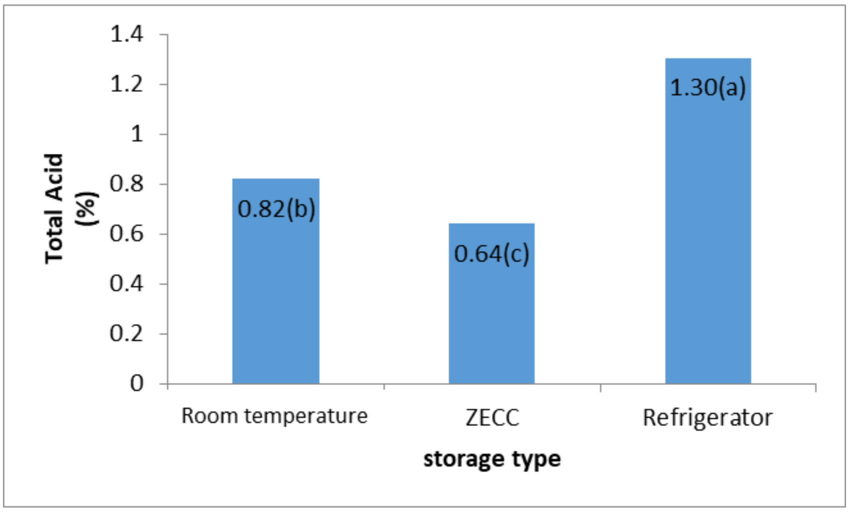


Figure 8. Relationship between Storage Type and Total Acid of Mango Fruit; values followed by different letters indicate significantly different results (p<.05).

The total acid value of mango fruit stored in three different types of storage can be seen in Figure 8, which shows that the total acid value of mango fruit stored in three types of storage obtained significantly different results. Storage in the refrigerator produces the highest total acid value of 1.303% and is significantly different from room temperature storage and ZECC. The total acid produced at room temperature storage was .82%, while in ZECC storage, the total acid value produced during storage was .639% and obtained the lowest total acid value from room temperature and refrigerator storage. Storage in the refrigerator can slow down the decrease in total acid because it is influenced by storage temperature; the lower the storage temperature used, the slower the rate of decrease in total acid in mango fruit. This happens because storing mango fruit at low temperatures can suppress metabolic processes so that changing organic acids becomes slow. According to (21), mango fruit stored at low temperatures tends to decrease the total acid compared to the percentage of total acid of mango fruit stored at 20°C (21).

The relationship between type of storage and length of storage for mango fruit on total acid parameters can be seen in Figure 9. The total acid of mango fruit with different storage types and storage durations can be seen in Figure 9. The total acid of mango fruit stored at room temperature, based on the graph above, shows that the total acid value decreases during storage with a shelf life of up to 9 days. The total acid of mango fruit stored in ZECC, based on the graph, shows that there is a decrease in total acid during storage and the shelf life is up to 15 days. The acidity decreases as the mango fruit matures, mainly due to the use of citric, ascorbic, and malic acid as substrates during the respiration process. This is due to respiration activities that require organic compounds (22). Mango fruit stored in the refrigerator, based on the graph, shows that the total acid value fluctuates and increases during storage with a shelf life of up to 21 days. Refrigerator storage can suppress the process of respiration in mango fruit so that there is no breakdown of organic compounds in the fruit. According to (23), it is stated that storage at low temperatures can inhibit the respiration process to maintain the total acid content of the fruit. The fluctuating results obtained for total acid in refrigerator storage are presumably due to errors during titration such as errors in determining the endpoint of titration, errors in reading titration volume, incorrect concentration of titration solution, and cleanliness issues with equipment used (24).

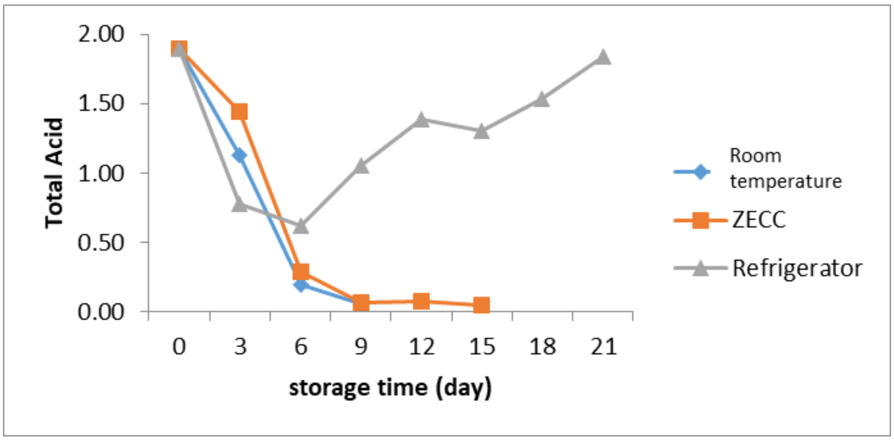


Figure 9. Relationship between storage type and storage duration on total acid of mango fruit.

3.5. Total Dissolved Solids

Measurement of total soluble solids can be shown with units of %brix, where the amount of dissolved sugar in fruit juice can be seen in the TPT measuring device commonly called a refractometer (25). The results of the analysis of variance showed that the type of storage (sig. .000) and the interaction between the type of storage and the length of storage (sig. .000) showed that the results obtained had a significant effect at the 5% level ($p \leq .05$) on the total soluble solids of mango fruit during storage so that Duncan's further test was carried out. Duncan's further test results for the type of storage showed that storage at room temperature had the highest total soluble solids value and was significantly different from storage in ZECC and refrigerator.

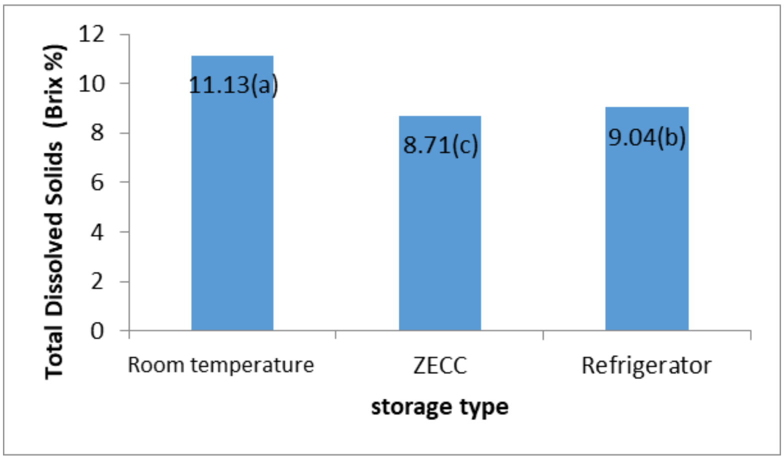


Figure 10. Relationship between storage type and total dissolved solids of mango fruit; values followed by different letters indicate significantly different results ($p<.05$).

The total soluble solids of mango fruit stored in the three types of storage can be seen in Figure 10, which shows that room temperature storage has the highest value of soluble solids and is significantly different from the two types of mango fruit storage, namely ZECC, and refrigerator. The type of storage in the refrigerator has the lowest value of total soluble solids. The value of total soluble solids in mango fruit storage is 11.133 %brix and significantly different from ZECC storage with a total soluble solids value of 8.711 %brix and mango fruit storage in the refrigerator as much as 9.02 %brix. Total soluble solids are influenced by storage temperature because during storage of mango fruit, there will be a decrease in fruit dryness which is influenced by the respiration process in mango fruit. This is by Kusumiyati et al., (2018) which states that mango fruit stored at room temperature will result in a decrease in hardness level drastically when compared to storage in controlled atmospheric conditions (17).

The relationship between the type of storage and the length of storage for mango fruit on the parameters of total soluble solids can be seen in Figure 11. Total soluble solids in mango fruit with different storage types and storage duration can be seen in Figure 11. Total soluble solids in mango fruit at room temperature storage, based on the graph above, show that the value of total soluble solids increases during storage and shelf life up to 9 days. The total soluble solids of mango fruit in ZECC storage, based on the graph above, show that the value of total soluble solids increases during storage, and the shelf life is up to

15 days. The total soluble solids of mango fruit in refrigerator storage, based on the graph above, show that the value of total soluble solids fluctuates and mostly increases during storage and shelf life until day 21. The results of the three storage types show an increase in total soluble solids during storage caused by starch hydrolysis. The increase in total soluble solids in mango fruit occurs due to the hydrolysis of starch by the enzyme amylase into glucose and fructose, which are used as substrates in the respiration process during mango fruit storage (22).

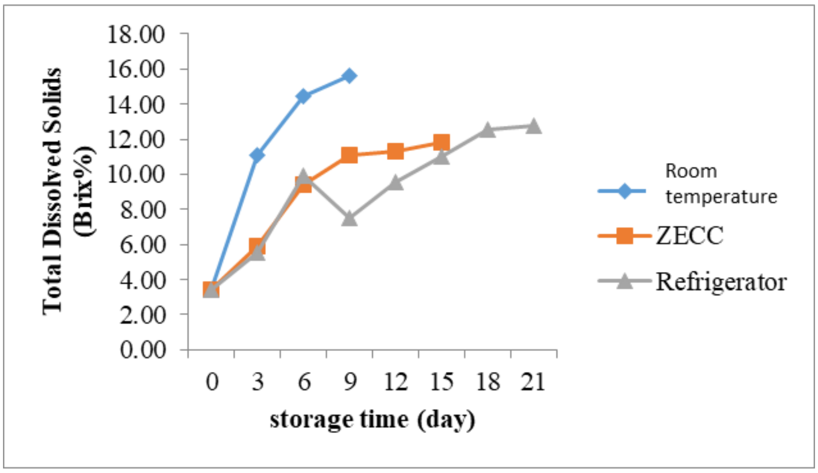


Figure 11. Relationship between storage type and storage duration on total soluble solids of mango fruit.

Qualitative color changes in mango fruit during storage at room temperature, zero energy cool chamber (ZECC), and refrigerator can be seen in Figure 12.

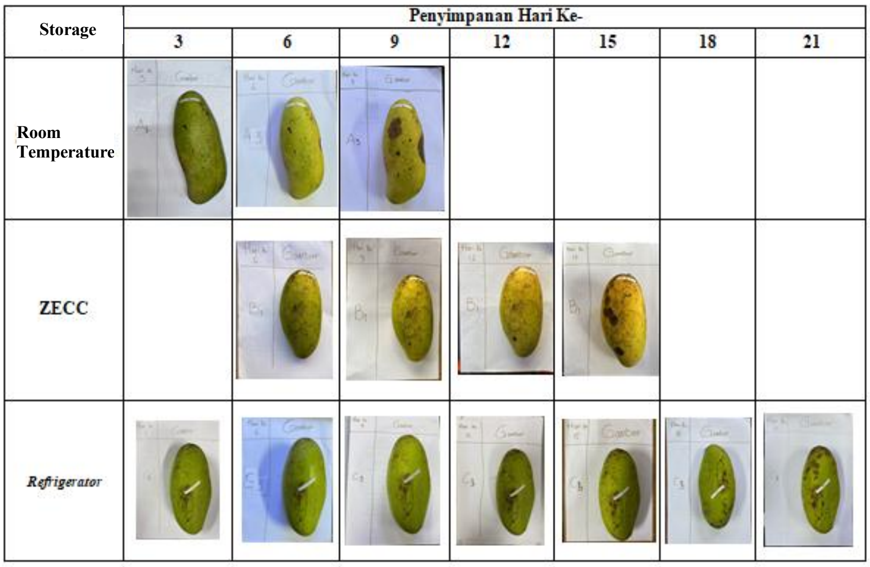


Figure 12. Qualitative Color Change During Storage of Mango Fruit.

In addition to the direct observation of mango fruit, observations were also made using a digital microscope. A digital microscope is a combination of an optical lens with a digital camera so that it can display images on a monitor screen such as a laptop screen or cell phone screen. The results of digital microscope observations of mango fruits stored in three different conditions: temperature, Zero Energy Cool Chamber (ZECC), and refrigerator, are shown in the figure above. Until the 21st day, observations were made at regular intervals. Under room temperature, the mangoes rotted quickly, with yellowing and black spots starting from day 3 and getting worse by day 9. Storage in ZECC slowed down the rotting process, with the mango fruit remaining green until day 9 and only showing more obvious signs of rotting on day 15. Whereas storage in a refrigerator, where the mango fruit showed almost no significant changes until day 9 and remained in good condition with only slight signs of decay until day 21 (26). Research has shown that ZECC can effectively extend the shelf life of mangoes by maintaining their quality and reducing physiological loss of water (PLW) and vitamin C degradation (27). The results of observations using a digital microscope during storage of mango fruit at room temperature, zero energy cool chamber, and refrigerator can be seen in the Figure 13.

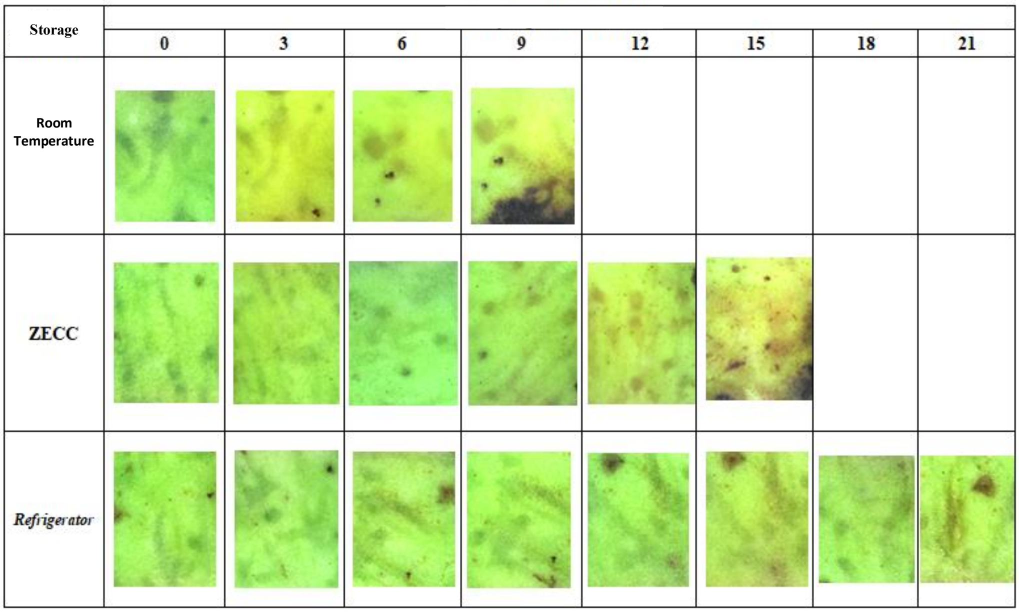


Figure 13. Color change during storage of mango fruit using a digital microscope.

4. Conclusions

The quality of mango fruit before storage in a zero-energy cool chamber is % weight loss, hardness level 62.63 N, Vitamin C 2.38%, and total acid 1.9%. Changes in the quality of mango fruit after storage in a zero-energy cool chamber are weight loss of 13.33%, hardness level of 2.47 N, Vitamin C 3.51%, and total acid of .05%. Golek Mango at room temperature storage can survive before day 9, zero energy cool chamber before day 15, and refrigerator before day 21 of storage.

Acknowledgments

Not applicable.

Author Contributions

M.A. and G.B. conceived and designed the experiments; M.A. performed the experiments; M.A analyzed the data; M.A. wrote the paper; M.A. monitored the planning and execution of the study

Funding

This research received no any external funding.

Institutional Review Board Statement

Not applicable.

Data Availability Statement

Available data are presented in the manuscript.

Conflicts of Interest

Author declared no conflict of interest.

References

1. Suci YT. Perubahan Mutu Buah Mangga Arumanis Selama Penyimpanan Dingin. AgriHumanis J Agric Hum Resour Dev Stud. 2020;1(2):99–106.
2. Dirpan A, Sapsal MT, Muhammad AK, Tahir MM, Rahimuddin. Evaluation of temperature and relative humidity on two types of zero energy cool chamber (ZECC) in South Sulawesi, Indonesia. IOP Conf Ser Earth Environ Sci [Internet]. 2017 Dec;101(1):12028. Available from: https://dx.doi.org/10.1088/1755-1315/101/1/012028
3. Islam MP, Morimoto T, Hatou K. Dynamic optimization of inside temperature of Zero Energy Cool Chamber for storing fruits and vegetables using neural networks and genetic algorithms. Comput Electron Agric [Internet]. 2013;95:98–107. Available from: https://www.sciencedirect.com/science/article/pii/S0168169913000823
4. Islam MP, Morimoto T. A new zero energy cool chamber with a solar-driven adsorption refrigerator. Renew Energy [Internet]. 2014;72:367–76. Available from: https://www.sciencedirect.com/science/article/pii/S0960148114004364
5. Dirpan A, Nurfaidah Rahman A, Tahir Sapsal M, M. Tahir M, Dewitara S. Color and Organoleptic Changes of the Golek Mango Fruit (Mangifera indica L.) On Zero Energy Cool Chamber (ZECC) Storage Method with Packaging Combination. J Agritechno. 2021;14(02):66–75.
6. Dirpan A, Sapsal MT, Syarifuddin A, Tahir MM, Ali KNY, Muhammad AK. Quality and Storability of Mango During Zero Energy Cool Chamber (ZECC). Int J Agric Syst. 2018;6(2):119.
7. Meindrawan B, Sugiyama N, Muchtadi T, Iriani E. Application of Carrageenan-based Bionanocomposite Coating for Maintaining Quality of Whole Mango Fruit. J Keteknikan Pertan. 2017;05(1):89–96.
8. Sugianti C, Hasbullah R, Purwanto YA, Setyabudi DA. Kajian Pengaruh Iradiasi Dosis

0.75 Kgy Terhadap Kerusakan Dingin (Chilling Injury) Pada Buah Mangga Gedong Selama Penyimpanan. J Tek Pertan LampungVol. 2014;3(2):195–204.
9. Putri MH, Septiyani P, Aryani W, Abriyani E. Literatur Riview: Penetapan Kadar Vitamin C Pada Buah Jambu Biji, Jeruk, Dan Nanas, Menggunakan Metode Spektrofotometri Uv-Vis. J Ilm Wahana Pendidik. 2023;9(4):333–42.
10. Lestari R, Hasbullah R, Harahap I. Vapor Heat Treatment and Storage Temperature for Maintaining Quality of Arumanis Mango (Mangifera indica L.). J Keteknikan Pertan. 2017;05(2):1–13.
11. Ilmi NK, Poerwanto R, Sutrisno S. Perlakuan Air Panas Dan Pengaturan Suhu Simpan Untuk Mempertahankan Kualitas Buah Mangga (Mangifera Indica L.) CV. Gedong. J Hortik. 2015;25(1):78–87.
12. Tefera A, Seyoum T, Woldetsadik K. Effect of Disinfection, Packaging, and Storage Environment on the Shelf Life of Mango. Biosyst Eng [Internet]. 2007;96(2):201–12. Available from: https://www.sciencedirect.com/science/article/pii/S1537511006003345
13. Sa’adah K, Susilo B, Yulianingsih R. Pengaruh Pelapisan Lilin Lebah dan Pengemasan Terhadap Karakteristik Buah Mangga Apel (Mangifera indica L.) selama Penyimpanan pada Suhu Ruang. In 2015. Available from:https://api.semanticscholar.org/CorpusID:190585590
14. Islam MP, Morimoto T, Hatou K, Sa’adah K, Susilo B, Yulianingsih R, et al. The chitosan affects severely the carbon metabolism in mango (Mangifera indica L. cv. Palmer) fruit during storage. Food Chem [Internet]. 2017 Dec;237(2):372–8. Available from: https://www.sciencedirect.com/science/article/pii/S1537511006003345
15. Nadeem A, Ahmed ZFR, Hussain SB, Omar AEDK, Amin M, Javed S, et al. On-Tree Fruit Bagging and Cold Storage Maintain the Postharvest Quality of Mango Fruit. Horticulture. 2022;8(9):1–14.
16. Harianto H, Anggraini D, Astuti A, Adinegoro H. Uji Metode Pengkelasan Tingkat Kematangan Buah Mangga Berdasar Posisi Buah di dalam Air. War Ind Has Pertan. 2020;37(1):41.
17. Kusumiyati, Farida, Sutari W, Mubarok S. Kualitas buah mangga selama penyimpanan pada keranjang anyaman bambu dengan identifikasi ruang warna L*,a* dan b* (Quality of mango fruit during storage on bamboo wicker basket usingL*, a*, and b* color space identification). J Kultiv. 2018;17(2):628–32.
18. Purwadi A, Usada W, Isyuniarto. Pengaruh Lama Waktu Ozonasi terhadap Umur Simpan Buah Tomat (Lycopersicum esculentum Mill). Pros PPI - PDIPTN. 2007;234–42.
19. Yuliati N, Kurniawati EG. Analisis Kadar Vitamin C Dan Fruktosa Pada Buah Mangga (Mangifera indica L.) Varietas Podang Urang Dan Podang Lumut Metode Spektrofotometri UV-VIS. In 2017.
Available from: https://api.semanticscholar.org/CorpusID:90843970
20. Rahman N, Ofika M, Said I. Analisis Kadar Vitamin C Mangga Gadung (Mangifera SP) dan Mangga Golek (Mangifera Indica L) Berdasarkan Tingkat Kematangan dengan Menggunakan Metode Iodimetri. J Akad Kim. 2015;4(1):33–7.
21. Syafutri M., F P, D S. Sifat fisik dan kimia buah mangga (Mangifera indica L.) selama penyimpanan dengan berbagai metode pengemasan. J Teknol dan Ind Pangan. 2006;vol XVII n.

22. Broto W, Kailaku SI, Jamal IB, Nurjanah R, Syaifullah E. Pematangan Buah Mangga (Mangifera indica, L.) CV. Gedong Menggunakan Gas Etilen. J Penelit Pascapanen Pertan. 2021;17(3):165.
23. Silaban SD, Erma P, Endang S, Silaban SD, Prihastanti E, Saptiningsih E, et al. Pengaruh suhu dan lama penyimpanan terhadap kandungan total asam , kadar gula serta kematangan buah terung belanda. Bul Anat dan Fisiol. 2013;Volume XXI:55–63.
24. Kurniawan B. Belajar Praktis Kimia Mata Pelajaran Peminatan Matematika Dan Ilmu Pengetahuan Alam. Klaten: Vivo Pakarindo; 2019.
25. Arifiya N. Prediksi Kandungan Pati Pepaya IPB9 Selama Penyimpanan dengan Spektroskopinir. STRING (Satuan Tulisan Ris dan Inov Teknol. 2017;1(3):265.
26. Mishra A, Jha SK, Ghimire K, Subedi U. Study on Zero Energy Cool Chamber (ZECC) for Storage of Mango. Int J Sci Res Publ. 2020;10(1):p9766.
27. Tolera H, Abera S, Tolesa GN, Belachew T. Effects of Zero Energy Evaporative Cooling Pads on the White Sapote (Casimiroa edulis L.) Fruit Quality and Storage Life. J Food Process Preserv. 2023;2023:1–11.