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ORIGINAL ARTICLE

EXTENDING OF MANGO (*MANGIFERA INDICA* L.) SHELF LIFE WITH COMBINATION OF ZERO ENERGY COOL CHAMBER (ZECC) STORAGE TECHNOLOGY, WASHING AND PACKAGING

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Abstract: Mangoes suffer up to a 20%-50% shrinkage, loss, and quality damage as a result of improper harvest and post-harvest handling, as well as poor storage conditions. The presence of a post-harvest technology system of Zero Energy Cool Chamber (ZECC) storage combined with pre-handling treatment (washing and packaging) is one method of minimizing damage and extending the shelf life of mangoes. This study aimed to determine the mango golek's quality and shelf life by using ZECC in combination with washing and packaging. This study used a completely randomized design (CRD) with factorial patterns, specifically factor A (storage type) and factor B (packaging and without packaging). The study's observation parameters were divided into two stages, with stage 1 consisting of physical parameters and stage 2 consisting of chemical, microbiological, and sensory parameters. According to preliminary research, the best treatment is washing with 1% detergent + 0.5 percent $Ca(OH)_2$, which results in a smoother skin surface, less noticeable discoloration, and a cleaner surface free of sap and dirt. Physical, chemical, microbiological, and sensory analysis of mango golek (*Mangifera indica* L.) demonstrates that the ZECC storage technique can maintain fruit quality optimally in combination with washing (chemical) and packaging treatment processes and it can effectively protect the mango golek's quality for up to 21 days.

***Key words*:** Fruit-quality, Postharvest technology, Cool chamber, Shelf life.

Cite this article

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1. Introduction

Indonesia possesses immense natural resource potential, particularly in horticultural crops like mango. According to the Indonesian Central Statistics Agency, mango production reached 2,431,329 tons per year in 2014 and 2,178,833 tons per year in 2015, a decrease of 10.39 percent. Mango productivity continues to be harmed by improper harvesting and post-harvest handling, which degrades the quality of the mangoes. Additionally, storage conditions are insufficient during agricultural product distribution and marketing, resulting in fruit depreciation. According to research conducted in developing countries, improper harvesting and post-harvest handling can result in fruit yield losses ranging from 20% to 50% [Dirpan *et al*. (2017)].

Cold storage is one technique for post-harvest handling. However, rural areas, which are typically agricultural centers, have severe shortages of cold storage, such as refrigerators. Additionally, the high operational costs associated with cold storage present a significant barrier to farmers employing post-harvest handlers. Additionally, it produces freon, an environmentally hazardous chemical [Dirpan *et al.* (2017)]. In light of the aforementioned issues, we require an energy-free (zero energy) cold storage system that is also affordable (low cost) and environmentally friendly (ecofriendly), one of which is the Zero Energy Cool Chamber (ZECC) [Islam and

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Morimoto (2015)].

The Zero Energy Cool Chamber (ZECC) is a cost-effective and environmentally friendly method of storing fruits and vegetables following harvest. Due to the fact that ZECC does not require electricity to operate, it is frequently referred to as an environmentally friendly fruit and vegetable storage system [Dirpan (2019), Islam *et al*. (2013)]. Additionally, this storage system is cost effective due to the fact that it makes use of readily available materials such as bricks, sand, plastic roofs and water [Dirpan *et al*. (2017), Islam *et al*. (2013)].

Recent years have seen an increase in research on fruit and vegetable storage methods utilizing ZECC, as demonstrated by Ali (2017) and Dirpan (2018) studied examining the quality of mangoes and tomatoes stored in ZECC [Ali (2017), Dirpan (2008)]. However, because fungi grew around the mangoes in the aforementioned studies, ZECC was used in conjunction with pre-handling treatments such as washing and packaging to minimize the possibility of mold and yeast growth and to extend the shelf life of the golek mango. As a result, the purpose of this research were: to determine the physical, chemical, microbiological and sensory characteristics of mango golek stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes and to determine the shelf life of mangoes stored in a ZECC (Zero Energy Cool Chamber) in combination with washing and packaging processes.

2. Materials and Methods

2.1 Date and Location of Research

This research was conducted from July to November 2019 at the Food Processing Laboratory and the Chemical Laboratory of Food Quality Analysis and Supervision of the Food Science and Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Hasanuddin University, as well as at the Research Activity Center (PKP) building and Lecturer Housing Unhas Tamanlarea, Makassar.

2.2 Instruments and materials

The tools used in this research include a zero energy cool chamber (ZECC), polypropylene plastic packaging, fruit racks, temperature and relative humidity sensors, hoses, scales, analytical scales and moisture, analyzer, colorimeter, penetrometer, digital hand refractometer, pH meter, stirring rod, beaker, erlenmeyer flask, volumetric flask, dropper pipette, volume pipette, petri dish, autoclave, bulp, micropipet, test tube, tube rack, laminar air flow (LAF), plates, spoons, knives, rags, blenders.

Materials used in this study were 77 golek mango (main ingredient) with a maturity index of 2 (light green), aquadest, detergent, chlorine, calcium hydroxide ($Ca(OH)_2$), sodium hydroxide (NaOH), iodine, indicator phenolphthalein, alcohol, buffer pH 7, mineral water, starch indicator (starch), potato dextrose agar (PDA) medium, inhibitor (chloramphenicol), cotton, and labels.

2.3 Research procedure

The research process is as follows:

2.3.1 Preliminary research

Mangoes are sorted, and then those that are not rotten or injured are selected for this research. The mango is then graded according to its maturity level. Following that, the Zero Energy Cool Chamber (ZECC) is chemically sterilized by spraying 0.5 percent chlorine + 70% alcohol. After that, the mangoes are prepared and washed using water, detergent, and $Ca(OH)_2$ in accordance with the treatment method. After washing, the mangoes were air-dried and then stored in two different conditions: ZECC and room temperature.

After that, the mango fruit was observed daily for changes until the eighth day of storage.

2.3.2 Main research

The following stage is mango that has received the best treatment during the washing process (1 percent detergent + 0.5 percent $Ca(OH)_2$), combined with post-harvest technology, specifically packaging techniques utilizing Polypropylene (PP) plastic, and then returned to the sterilized ZECC. Each day, the fruit is analyzed for damage, which is defined as shriveling, softening, dull skin color, the appearance of black spots on the fruit's skin, and the presence of mold at the fruit's base.

2.4 Research design

The design of the research is divided into two stages. The first stage is to determine the optimal treatment for washing mangoes using various washing ingredients, with the following treatments:

A_0 : Control (Without washing).

A_1 : Water-based cleaning.

A_2 : 1% detergent + 0.25% $Ca(OH)_2$.

A_3 : 1% detergent +0.5% $Ca(OH)_2$.

Following with storage in ZECC and at room temperature, physical parameters of the fruit skin surface, color, sap and impurities were observed visually.

The next step is mango that received the best treatment during the washing process, combined with packaging techniques utilizing Polypropylene (PP) plastic. It is then analyzed every three days using a variety of observation parameters.

2.5 Data analysis

The data obtained in the second phase of the study were compiled using a completely randomized design (CRD) with a factorial pattern, namely factor A (type of storage) and factor B (packaged and unpackaged). The research was carried out with three replications.

Data processing used quantitative descriptive method, all parameters were analyzed by analysis of variance (ANOVA) with three replications. The differences for each treatment were further tested using Duncan's test. The software used for data processing is Microsoft Excel 2016 and IBM SPSS Statistics Version 23.

2.6 Observation parameter

Observation parameters in stage 1 are physical parameters of fruit skin surface, color, sap and dirt. Parameters observed in stage 2 include vitamin C, pH value, water content, total acid, total dissolved solids, weight loss, skin color, hardness test, total microbe, and organoleptic test using 15 panelists.

3. Results and Discussion

3.1 First phase of research

The results of the storage of mangoes from the preliminary study showed that mangoes stored at ZECC had better physical quality (visually) than mangoes stored at room temperature. Mangoes stored in ZECC had smoother skin, less noticeable skin discoloration until the 8th day of storage, fewer lenticel spots, and did not grow fungus on the skin surface. The fruit that was stored at room temperature with a rougher skin surface (wrinkled), slightly noticeable skin discoloration, lenticel spots began to appear on the 5th day of storage, as well as fungal growth in some mango samples. These results indicate that storage using the ZECC method is good for extending the shelf life of mangoes compared to storage at room temperature.

3.1.1 Mango Skin Surface

Visual observations of the mango skin's surface revealed that ZECC storage was better compared to room temperature storage. Mango fruits stored in ZECC had smoother skin (not wrinkled) than mango fruits stored at room temperature, which had wrinkled skin surface. The absence of wrinkles in mangoes stored at ZECC is due to the relative humidity (RH) in a good storage room, which is between 80% and 98.04 percent, as opposed to room temperature, which has a relative humidity of 50% to 56.90 percent. This is consistent with Muchtadi (1992), who states that all varieties of mango are susceptible to cold damage in the form of dark spots, uneven ripening, and failure to produce adequate flavor and color, and that a relative humidity of 85-90 percent is required to prevent wilting and softening of various fruits and vegetables [Muchtadi (1992)].

The room temperature is higher than the temperature in the ZECC. ZECC has a temperature range of 24-25^{o}C, while the ambient temperature ranges from 26-31^{o}C. Mango fruit stored at room temperature transpired and respired at a faster rate than mango stored in ZECC, causing the mango skin to wrinkle. Because respiration rate is related to the rate of quality deterioration, it can be used to estimate the shelf life of fruit after harvest. As stated by Rizkia (2004) that the slower the rate of respiration, the longer the fruit can be stored in its fresh state; conversely, the faster the rate of respiration, the shorter the shelf life.

3.1.2 Skin color

Mangoes are generally observed visually by observing how clearly the color change from green to yellow appears on the mango skin. Mangoes stored at room temperature and in ZECC without treatment/ washing (control), as well as those washed with water and detergent + $Ca(OH)_2$ exhibited no discernible color changes. On the sixth day of observation, the color changed to a slight yellow hue. This color change occurs because mangoes, as climacteric fruits, accelerate the ripening process during storage. The maturation process that occurs concurrently with the breakdown of chlorophyll, resulting in the appearance of other color pigments such as yellow and red, causing the green color to degrade. This is in line with El-Zeftawi *et al*. (1988), who stated that the level of chlorophyll content in green fruit decreases during the storage, other pigments begin to appear, turning the fruit yellow or orange.

3.1.3 Sap and Dirt

For mango fruit washed with water, on day 6 DAW (day after washing), there were still remnants of sap attached to the surface of the mango fruit skin, although they were not particularly noticeable. However, there were a few lenticel spots and a change in color at the fruit's base on day 6 DAW (day after washing) until the 8th day of DAW. While mangoes treated with 1% detergent + 0.25 percent $Ca(OH)_2$ can visually remove sap, the treatment was more effective at 1% + $Ca(OH)_2$ 0.5 percent detergent immersion, which resulted in samples of mango fruit being more free of sap and dirt, resulting in a smoother surface with no noticeable changes up to 8 DAW. This is because 1% detergent binds to oil and effectively removes or lifts dirt. Until the eighth day after DAW mango was treated with 1% detergent and 0.5 percent $Ca(OH)_2$, no lenticel or fungal spots appeared at the base or on the surface of the fruit skin. The surface is smoother and burn-free because the detergent's surfactant active ingredients can remove the oil contained in the sap. Alkaline $Ca(OH)_2$ solution can neutralize the acid in the sap attached to the golek mango cultivar's skin. This is consistent with Ahmad *et al*. (2017)'s finding that the 1% + $Ca(OH)_2$0.5 percent detergent treatment resulted in a lower mean score for reducing lenticel spots at 2 to 14 DAW when compared to the control. In accordance with Taqiyyah (2015), a combination of detergent and $Ca(OH)_2$ is capable of removing sap and oil from the surface of the Gedong mango skin.

3.2 Second phase of research

The second stage of this study involved determining the quality and shelf life of mangoes while they were stored. Mangoes that received the best washing treatment (1 percent detergent + 0.5 percent $Ca(OH)_2$) were then given packaging treatment (using Polypropylene (PP) plastic and without packaging) and then analyzed for quality. Mangoes packaged with Polypropylene (PP) plastic can be stored in ZECC for 21 days, whereas mangoes packaged without Polypropylene plastic have a shelf life of only 18 days.

3.2.1 Weight Loss

The results of weight loss analysis are summarised in Fig 1. During storage, the mango fruit's weight loss tends to increase. Unpackaged mangoes (ZT) lost approximately twice as much weight as packaged mangoes (ZK). This means that when packaging is used in combination with the ZECC storage technique, mangoes lose less weight. Unpackaged mangoes experienced a greater increase in weight loss due to a high evaporation rate (transpiration), whereas packaged mangoes experienced less water evaporation during storage. Water loss results in withering and shrinking. This is consistent with Winarno (2002), who states that the amount of water in foods determines their freshness, appearance and durability. If some of the water in the food evaporates, weight loss occurs, reducing the food's freshness, appearance and durability.

In addition to transpiration, weight loss is also influenced by the respiration process of mango fruit. Carbon loss can occur during the respiration process. Carbon compounds contained in the sugar in mangoes will bind and react with oxygen which will produce simple volatile compounds, namely water vapor and carbon dioxide so that the fruit will lose its weight. So in this case it is known that the respiration process can be suppressed by a combination of packaging and storage in ZECC. This is in accordance with the opinion of Syafutri *et al*. (2006), who stated that the process of fruit respiration can be suppressed by combining packaging and storage at low temperatures.

3.2.2 Hardness Level

The Fig. 2 provides a quantitative analysis of the hardness level of mango. The ripening process of mangoes during storage results in changes in the level of mango fruit hardness. The ripening process in mangoes occurs concurrently with the conversion or degradation of protopectin to pectin, resulting in a decrease in cell wall rigidity. Mangoes without packaging treatment (ZT) had a greater loss of hardness than mangoes with packaged treatment (ZK). This is due to the fact that unpackaged mangoes have a higher respiration rate and a higher enzyme activity. The more actively these enzymes are the softer the texture of the fruit. Meanwhile, the rapid rate of respiration causes the fruit tissue to rupture, resulting in the mango becoming soft. The mango with packaging treatment (ZK) can reduce the amount of oxygen received, thereby slowing the respiration process (maintained). This is consistent with Syafutri *et al*. (2006), who stated that the decrease in hardness is also a result of the respiration and transpiration processes. The respiration process results in the breakdown of carbohydrates into simple compounds and tissue rupture, resulting in the mango becoming soft, whereas the transpiration process results in water evaporation, resulting in the mango becoming wilted.

3.2.3 Vitamin C Levels

The levels of vitamin C (ascorbic acid) of mangoes during storage in ZECC tend to vary, both packaged in polypropylene plastic and mangoes without packaging as can be seen in Fig 3. The significant increase in vitamin C levels of unpackaged mangoes until the end of storage was in line with the faster ripening process of mangoes compared to packaged mangoes. This is in accordance with Pantastico (1986), who stated that ripe fruit will increase in acidity, and this increase occurs simultaneously with the climacteric pattern, while vitamin C levels will decrease when the maximum point of increase has been exceeded (withering stage). The ripening process of unpackaged mangoes is faster because the respiration process is greater than that of packaged mangoes. Mango packaging can regulate/ minimize the respiration process of the fruit so that the freshness of the mango can be maintained. This is in accordance with Park *et al.* (2004), who stated that Polypropylene (PP) plastic has high permeability properties, which can regulate the rate of atmospheric absorption or respiration rate which can maintain fruit freshness longer. The results of analysis of variance showed that mango without packaging treatment and mango with packaging treatment had a significant effect on vitamin C levels during storage. This is indicated by the value of vitamin C which was initially low and then increased until the end of storage. The increase or decrease in vitamin C is because the vitamin is unstable, easily oxidized when exposed to air (oxygen) and this process can be accelerated by storage temperature. This is in accordance with Tannenbaum (1976), stating that the reduction of O_2 will inhibit the degradation of ascorbate into dehydroascorbic acid and H_2O_2 [Tannenbaum (1976)]. The resulting H_2O_2 will cause autoxidation so that it will increase the damage of vitamin C.

3.2.4 Total Acid

The Fig. 4 outlines the results of the total acid level. The total acid value of mango in ZECC storage, both packaged and unpackaged, tends to decrease, though the trend is variable. The percentage of total acid in the fruit decreases as the fruit is stored. The decrease in the percentage of total acid is due to the respiration process's use of organic acids, as well as the use of organic acids by microbes in energy-consuming activities. This energy is obtained through the breakdown of the nutrients found in food. Organic acids

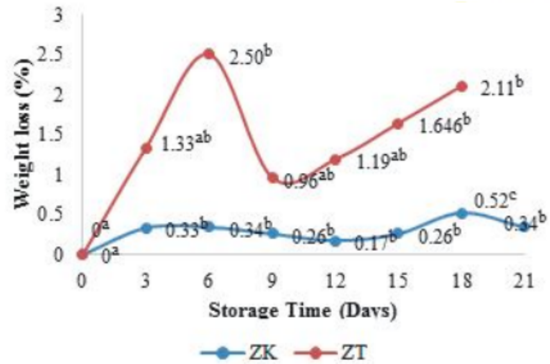

Fig. 1: The weight loss of Mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

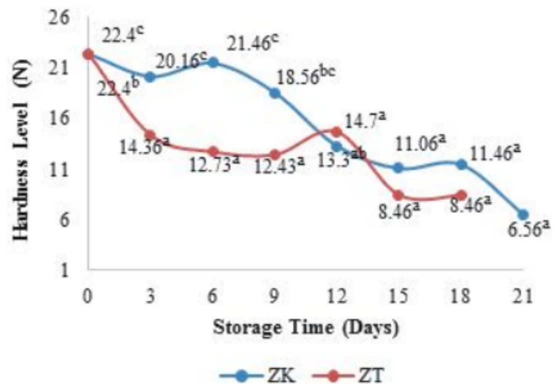

Fig. 2 : The Hardness level of Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

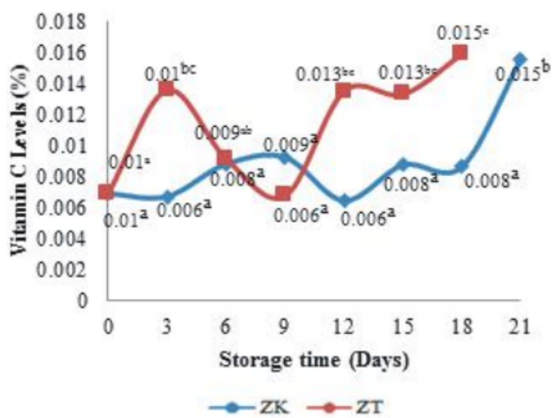

Fig. 3: Vitamin C levels of Mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

are converted to sugars during the respiration process. Khairi *et al*. (2017) found in their research that the fruit's decreased organic acid value indicated that the fruit's ripening metabolism was functioning normally [Khairi *et al*. (2017)].

Total acid in mangoes that were not packaged (ZK) degraded more rapidly than in packaged mangoes (ZK). This is due to the respiration process of unpackaged mangoes. Syafutri *et al*. (2006) stated that when mangoes are not packaged, the respiration process cannot be minimized due to the abundant O_2 in the environment [Syafutri *et al*. (2006)].

3.2.5 Total Dissolved Solids (TDS)

In Fig. 5 we present a detailed evaluation oftotal dissolved solids. Mangoes' total dissolved solids (packaged and unpackaged) exhibit a fluctuating graph. Unpackaged mangoes (ZT) underwent a maximum ripening process, as indicated by the percentage of TDS value increasing significantly at first and then gradually decreasing until the end of storage. The increase in TDS is a result of starch hydrolysis during ripening process. While the decrease in TDS occurs as a result of the abundant O_2 available in the environment. It may be which contributes to the respiration process. Thus, glucose as the result of starch hydrolysis then was consumed during the respiration process, resulting in a rapid decrease in the sugar content of the fruit. Pantastico (1986) confirmed this by stating that during ripening, starch is hydrolyzed into simple compounds that serve as a source of energy during the respiration process [Pantastico (1986)]. At this point, the sucrose has been converted back to glucose and fructose. The decrease in total sugar content of unpackaged mangoes occurred as the mango fruit began to ripen, at which point the starch content began to decrease and the activity of the invertase enzyme decreased, resulting in a decrease in sugar content. The mango with packaging (ZK) has the ability to maintain the fruit's ripening process, as indicated by the predominant fluctuating TDS value. This demonstrates that by combining packaging and storage in ZECC, the rate of decrease in the percentage of TPT in mangoes can be slowed.

This variable total dissolved solids value is also a result of the fruit's non-uniform maturity level. Non-uniform fruit ripeness causes abnormal respiratory activity so that the breakdown process of simple sugars varies. In general, changes in total dissolved solids

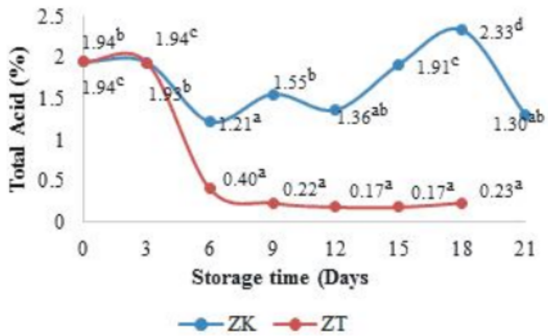

Fig. 4: Total acid level of Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

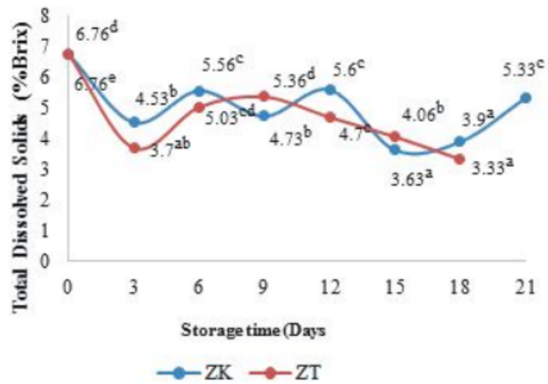

Fig. 5: Total dissolved solids of mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

content increased at the maximum point of storage and then decreased until the fruit began to rot on the final day of storage. This is consistent with Biale and Young's (1971) observation that the general trend is for a rapid increase in sugar content followed by a decline; in climacteric fruit, this condition becomes a marker.

3.2.6 Degree of Acidity (pH)

According to the Fig. 6, mango fruit are acidic, with a pH value ranging between 2 and 6 during storage. The ripening of mangoes alters the pH value of the fruit. Without packaging treatment (ZT), mango matured rapidly (maximum), increasing the pH value. It is not the case with packaged mangoes (ZK), as their ripening process is slowed, resulting in a stable pH value throughout storage. As the mango ripens, the acid content decreases while the simple sugars increase, as indicated by the decrease in total acid content. The pH value is directly proportional to vitamin C levels and inversely proportional to total acidity. This is consistent with Khairi *et al*. (2017), who stated that changes in pH indicate changes in the composition of the fruit's cell fluid as it matures; the pH value that tends to be high is related to relatively high ascorbic acid (vitamin C) levels during storage. This change indicates that the fruit's metabolism affects the pH value [Khairi *et al.* (2017)].

3.2.7 Water content

The water content of mangoes stored in the ZECC method varied slightly during storage that we can see in Fig. 7. When compared to unpackaged mangoes, packaged mangoes (ZK) are able to maintain changes in water content during storage. This is because PP packaged mangoes have a high permeability, which minimizes changes in water content during storage. This is consistent with Schwartz (2009), who stated that because of the packaging, ambient air cannot easily enter the material, thereby inhibiting the process of water exchange during storage.

Due to the high humidity in ZECC storage, which reached 80-95 percent, mango fruit experienced an increase and decrease in water content during storage. Due to the high humidity level in the ZECC room, moisture absorption from the environment into the stored mango is possible. The longer the storage time, the higher the water content will remain. According to Herawati (2008), a significant factor influencing the decline in the quality of food products is changed in the product's water content, which can be influenced by the room's temperature and humidity during storage. This opinion is backed up by Retnani *et al.* (2009) who stated that the high humidity of the storage room can result in the absorption of water vapor from the air into the foodstuffs, resulting in an increase in water content.

Additionally, the increase in water content during storage is a result of the mangoes' respiration process. During storage, the fruit undergoes a ripening process that includes the conversion of starch to simple sugars ($C_6H_{12}0_6$). These simple sugars then interact with the oxygen (O_2) in the chamber, increasing the rate of water (H_2O) formation in the fruit. This is consistent with Rizkia (2004), who stated that one of the causes of changes in the water content of fruit is the respiration process, during which water is formed as a result of sugar reorganization into simpler compounds.

3.2.8 Color

Based on the results in Fig. 8, we make the following observations. The L* value indicates the brightness level of the mango fruit, which indicates the reflected light that produces achromatic colors of white, gray and black, *i.e.* from a value of 0 (black)-100 (white). The L* value of unpackaged and packaged mangoes had a very small decrease in lightness value during storage. The range of changes in the L* value from 65-62 indicates a slight decrease in brightness level during storage. The longer the fruit is stored, the lower the brightness level of the mango. According to Ahmad *et al*. (2014), that the brightness level of the color will decrease which will be directly proportional to the longer the shelf life, the fruit will lead to spoilage in the end. The decreasing brightness level of the mango skin color is caused by changes in the chlorophyll content of the fruit. This is in accordance with the statement of Syafutri *et al*. (2006), who stated that the reduced level of color brightness in fruit during storage is caused by reduced chlorophyll content in fruit skins and the appearance of carotenoids.

The a* value is a value that shows the gradation of green to red. A mixed red-green chromatic color with a value of +a* (positive) from 0 to +80 for red and a value of –a* (negative) from 0 to -80 for green. The a* value of mango tends to increase during the storage process. Mangoes tend to be green, indicated by an a* value below 0, but the longer the storage time, the color of the fruit moves to red. The significant increase in a* value was caused by the high respiration rate of unpackaged mangoes so that the degradation of chlorophyll was also rapid which had the effect of accelerating the synthesis of pigment (color change) of the fruit. This is in accordance with the opinion of Masfufatun *et al*. (2009), who stated that a high respiration rate will also cause chlorophyll degradation and pigment synthesis to be fast, consequently accelerating color changes.

The b* value indicates the color gradation to yellow. A mixed blue-yellow chromatic color with +b* (positive) value from 0 to +70 for yellow and -b* (negative) value from 0 to -70 for blue. Based on the Fig. 8, it shows that unpackaged mangoes have a slowly increasing b* value during storage compared to packaged mangoes whose b* values tend to be stable until the end of storage. The results of the measurement of the b* value show

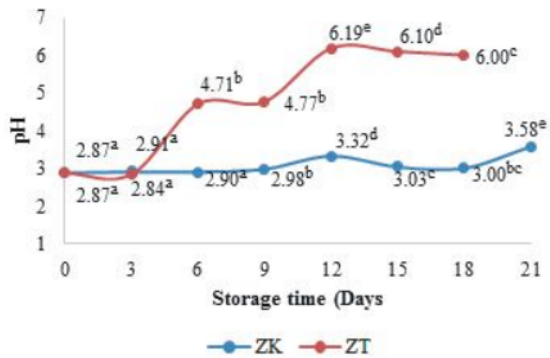

Fig. 6: pH value (Degree of acidity) Mango fruit during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$).

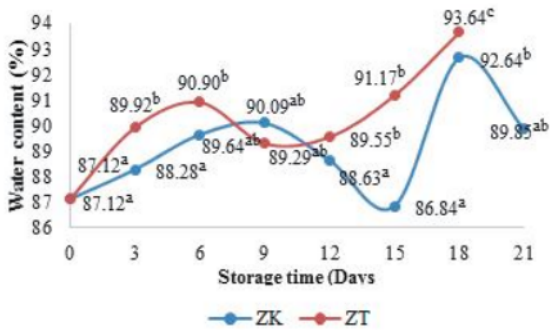

Fig. 7: Water content of mangoes during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

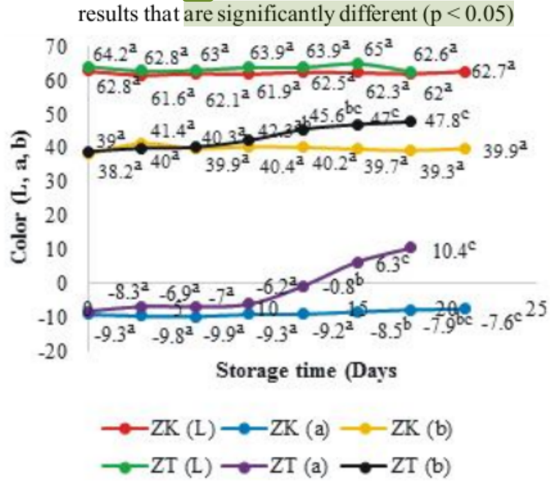

Fig. 8: Analysis of mango skin color during storage. Values followed by different letters indicate treatment results that are significantly different ($p < 0.05$)

that the longer the storage, the yellow color of the mango will be clearer. The increasing b* value in unpackaged mangoes indicates that the fruit is getting more mature than the packaged mangoes during storage.

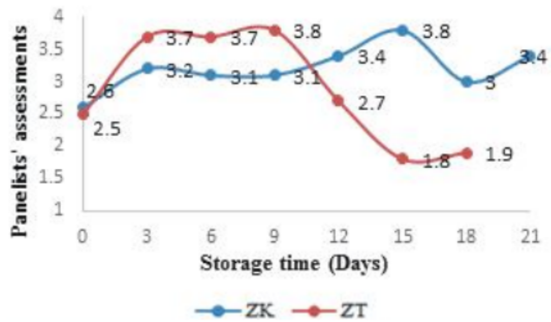

Fig. 9: Results of Organoleptic testing on mango color in ZECC storage

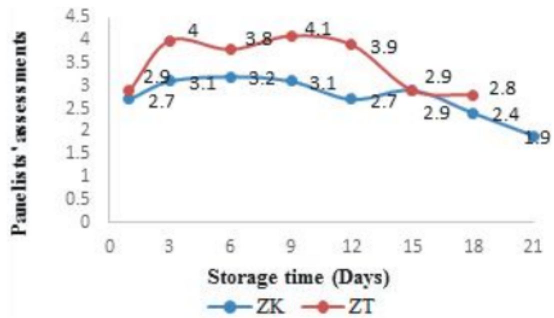

Fig. 10: Results of organoleptic testing on mango aroma in ZECC storage

3.2.9 Organoleptic test

Color: The Fig. 9 summarises and discusses the main findings of the of organoleptic color.The changes in panelists' assessments of organoleptic color parameters in mangoes were due to the nature of mangoes undergoing post-harvest ripening (after harvesting), specifically that the color will change during the storage process due to chlorophyll degradation into other pigments. The panelists' assessment of mangoes with packaging treatment (ZK) tended to remain stable until the end of storage, with an average value of 3 (slightly similar), whereas mangoes without packaging (ZT) maintained an average value of 4 (similar) until the ninth day of storage, when it decreased until the end of storage. This demonstrates that mangoes treated with packaging can help preserve or delay the color change of mangoes stored in ZECC. Packaging treatment on mangoes can slow the respiration process, resulting in a slower color change and maturation and aging process. This is consistent with Ali (2017), who stated that a faster respiration rate can accelerate the senescence process, which results in a more rapid color change.

Aroma: The panelists' evaluations of the mango aroma parameters revealed a range of results but a consistent pattern of increasing and then decreasing until the end of storage. In terms of fruit aroma, panelists prefer the unpackaged aroma of mango fruit fruit as can be seen in Fig.10.

The high acceptance of unpackaged mango aroma (ZT) is a result of the increasing ripening process (perfect ripening), which results in an increase in the production of volatile components.

While, the packaged mango (ZK) took longer to decompose, the panelists generally disliked it due to the incomplete ripening process, which resulted in a low flavor. This is consistent with Muchtadi (1992), who stated that ripening typically results in an increase in the content of simple sugars, which imparts a sweet flavor, as well as an increase in the production of volatile substances, which imparts a distinctive fruit flavor.

Taste: The results of the taste are summarised in Fig. 11. The results of organoleptic taste on mangoes stored at ZECC showed that the panelists' assessment of fruit taste increased and then decreased until the end of storage. The range of values between 3-5 (based on the graph) shows that the panelists' assessment of unpackaged mangoes (ZT) is dominantly preferable to mangoes with packaged treatment (ZK) with a value of 2-3. The high rating for unpackaged mangoes is because the mangoes undergo an even ripening process during storage, resulting in a distinctive taste and good color which is preferred by panelists [Ali (2017)]. The sweet taste is due to the change in the starch content of the fruit to sugar during storage. This is in accordance with the statement of Mulyati (2012), that changes during the ripening process are changes in starch and fat reserve materials into various sugars. The mango with packaging (ZK) undergoes a slow ripening process due to its low respiration rate in the presence of packaging, but it takes longer to decay or damage in ZECC storage.

Texture: Fig. 12 illustrates results of mango's texture. Panelists determined that mango with packaged treatment (ZK) (mean value 3-4) was preferable in terms of texture because the level of hardness did not decrease significantly (soft), as opposed to mango without packaged treatment (ZT) (mean value 2-3). The texture began as hard, which the panelists disliked, then softened slightly, which the panelists liked, and finally became extremely soft due to damage/rotting,

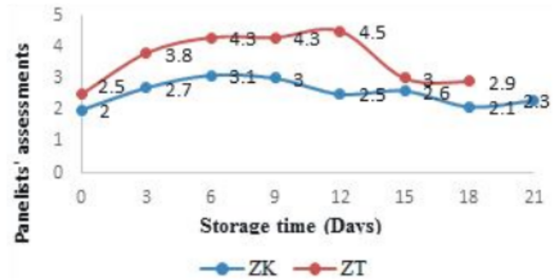

Fig. 11: Results of organoleptic testing on mango taste in ZECC storage

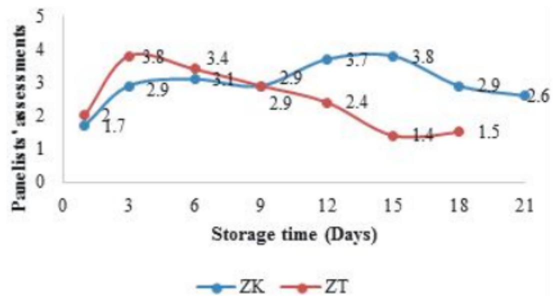

Fig. 12: Results of organoleptic testing on mango texture in ZECC storage

which the panelists disliked. When the qualitative (organoleptic test of texture parameters) analysis of mango fruit is combined with quantitative analysis (with a penetrometer), it is discovered that the level of hardness (the process of hardness decreasing) is directly proportional during storage.

Mangoes' softening texture is caused by the ripening process that occurs during storage. Maturation occurs concurrently with the conversion or degradation of insoluble protopectin to soluble pectin. The reshuffle occurs as a result of the action of enzymes such as pectin methyl esterase, which softens the fruit. Proteopectin levels in the fruit decrease as the fruit ripens, while pectin levels increase. This is in accordance with Johansyah and Kusdiantini (2014), that as fruit ripens and stores, some of the water-insoluble protopectin converts to water-soluble pectin, reducing the cohesion of the cell walls that connect cells, resulting in a decrease in texture or fruit hardness and the fruit becoming soft [Johansyah and Kusdiantini (2014)]. Additionally, the rate of respiration has an effect on the degree of hardness or texture. Unpackaged mangoes with a high respiration rate cause the fruit's tissue to rupture and enzyme activity to accelerate, resulting in a softer fruit texture. The mango with packaging treatment (ZK) can reduce the amount of oxygen

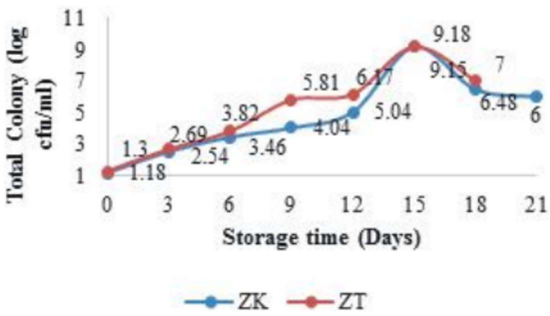

Fig. 13: Mold and yeast cell count on mangoes during storage in ZECC

received, thereby slowing the respiration process (maintained).

3.2.10 Microbial Analysis (Yeast Mold Count)

According to the Fig. 13, the results of microbial analysis (mold and yeast counts) on mango fruit storage in ZECC indicated that yeast mold growth continued to increase and then decreased gradually until the end of storage. Microbial growth (mold and yeast) that began low/small and then increased to a maximum growth peak on the 15th day generally indicated that the mangoes' quality deteriorated during storage and gradually entered the senescence phase. This also demonstrates that mangoes with a relatively high sugar content and a low pH provide an ideal environment for molds and yeasts to grow to their maximum growth capacity during storage. This is consistent with Rawat (2015) statement that fruit with a high sugar content and a low/acidic pH (pH range between 3-8) promotes the growth of fungi (mold/yeast) after the fruit is harvested .

Mango without packaging (ZT) exhibited a greater increase in the growth of the dominant mold/yeast than mango with packaging (ZK). This demonstrates that by combining calcium hydroxide washing with packaging on mangoes stored in ZECC, the rate of microbial growth can be slowed or suppressed, thereby extending the fruit's life phase. Certain microbes require oxygen to grow, which can be suppressed through packaging. This is consistent with the opinion of Mulyawanti *et al*. (2017), who stated that treating fruit with packaging technology can suppress the air activity required by microbes, thereby slowing the growth rate of pathogenic microbes [Mulyawanti *et al*. (2018)].

4. Conclusion

It can be concluded that analysis of the quality of golek mango (*Mangifera indica* L.) physically, chemically, microbiologically, and sensory in the Zero Energy Cool Chamber (ZECC) storage technique shows that ZECC can maintain optimal fruit quality through a washing treatment process (chemically) in combination with packaging. In addition, the Zero Energy Cool Chamber (ZECC) storage method with a combination of washing and packaging treatments is effective in maintaining the quality of mangoes up to 21 days of storage.

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