

Effects of Storage Containers on Postharvest Properties of Tomato (*Solanum lycopersicum* L.)

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Abstract

This study investigated the effect of three storage containers on postharvest properties of tomato fruits under ambient temperature, $30 \pm 3^\circ\text{C}$ and relative humidity, $70 \pm 3\%$. In Nigeria, the main issues with tomato preservation are loss of quality and shortened shelf life. Postharvest storage containers are important for maintaining the quality of tomato fruits in marketing chains and consumption. Raffia baskets, plastic bowls and Ziploc bags were used to store tomato fruits for seven days. The experiment was arranged in a completely randomized design with four replications. Data was taken on weight loss, dry matter, moisture content, pH, total ash content and colour. Results revealed that the storage containers had significant ($p < 0.05$) effect on dry matter, moisture content and weight loss of the tomato fruits. Tomato fruits stored in raffia basket, plastic bowl and Ziploc bag gave moisture content of 92.13%, 93.07% and 92.97% at seven days of storage, respectively. There was no significant difference ($p > 0.05$) in the effects of the three storage containers on total ash content and pH of the tomato fruits. For efficient storage without excessive deterioration, plastic bowls were considered the best storage container for improved shelf-life of tomato fruits.

Keywords: Composition, containers, fruits, properties, storage.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the most cultivated vegetable in the world (Srinivas *et al.*, 2019). It is a dicot plant belonging to the Family Solanaceae, which

comprises more than 3,000 species and major vegetables grown and consumed all over Nigeria with a total production of 4.1 million tonnes in 2018 (Osunmuyiwa *et al.*, 2021). The total world tomato production for both processing and consumption in 2021 was more than 189.1 million metric tonnes (FAO, 2022). Due to the scale of production and

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level of consumption, tomato is a preferred crop especially among small scale farmers and this represents 90% of total production (FAO, 2021). Nigeria is the second largest producer of tomatoes in Africa and ranks twelfth globally (Babadara, 2023).

Tomato contains minerals, vitamins, proteins, essential amino acids (leucine, threonine, valine, histidine, lysine, arginine), monounsaturated fatty acids (linoleic and linolenic acids), carotenoids (lycopene and β -carotenoids) and phytosterols (β -sitosterol, campesterol and stigmasterol) (Ali *et al.*, 2021). A tomato - rich diet is known to offer several health benefits attributed to their antioxidant content (Bhowmik *et al.*, 2012). Tomato fruits may also help to reduce the risk of cardiovascular disease, with studies showing associations between tomato consumption and a reduction in hypertension and the risk of atherosclerosis (Edward *et al.*, 2022). Despite its high nutritional values, health benefits and uses, this vegetable being a climacteric fruit has a short shelf-life once harvested (Okudu and Okeke, 2021). It is very difficult to store tomato at ambient temperatures for a long time because they ripen very quickly, lose market value within a short period and even rendered useless for domestic use after purchase for consumption. It is a perishable fruit with a relatively short shelf life, whose quality and nutritional values are affected by postharvest handling and storage conditions (Garuba *et al.*, 2017). Due to increase in demand for fresh fruits and vegetables, there is a need to develop improved method for maintaining product quality and freshness (Babarinde and Fabunmi, 2009). Zewdie *et al.* (2022) reported that application of beeswax coating in combination with neem leaf extract dipping significantly increased the shelf life of tomato fruits indicating a decrease in the percent decay and changes in the quality of

tomato fruits during 36 days of storage period.

Sualeh *et al.*, 2020 reported a significant difference in firmness values of stored tomato fruit due to the effect of storage condition. This study was therefore, carried out to determine the effect of storage containers on some physicochemical properties of tomato.

MATERIALS AND METHODS

Freshly harvested `Roma` tomato fruits were purchased from an identified farmer in Ilorin and transported to the laboratory of the Department of Crop Protection, Faculty of Agriculture, University of Ilorin, Ilorin. Storage containers – Ziploc bag (22cm x 17 cm) and plastic bowls (5cm x 4cm diameter) were obtained from Edinwo supermarket while raffia baskets (5.5cm x 6.5cm diameter) were purchased from Ganmo market in Ilorin. The tomato fruits were sorted and cleaned under running tap, air-dried for one hour in dry rectangular plastic trays (60cm x 55cm) that had been lined with tissue paper. The tomato fruits were visually selected for similarity in size, colour, and absence of physical damages. Each storage container had 10 medium size (90-100 g) tomato fruits weighing 800g and were arranged in a completely randomized design with four replications on the laboratory bench under prevailing ambient temperature ($30 \pm 3^\circ\text{C}$) and relative humidity ($70 \pm 3\%$).

Data collection

Tomato fruits in each storage container were examined at setup and on the seventh day after setup. Data was collected on dry matter, moisture content, pH, ash content, colour and weight loss at the end of the experiment.

Moisture Content

Moisture content of the tomato sample was determined using the method described by AOAC (2004). From each storage container, 10 g of the tomato fruit was taken, sliced and transferred into a Petri dish, and oven dried at 100°C for 24 hours. The difference in the weight of the samples (weight before oven dry and weight after oven dry) was recorded and moisture content calculated using the formula below:

Dry Matter %

$$= \frac{(\text{Petri dish} + \text{Sample after drying}) - \text{Petri dish weight}}{\text{Sample weight}} \times 100$$

$$100 = \text{MC} + \text{DM}$$

$$\text{DM} = 100 - \text{MC}$$

$$\text{MC} = 100 - \text{DM}$$

where MC = moisture content

DM= dry matter

pH

The pH of tomato sample was determined using a digital pH meter (Model Helmreassin pH meter PHS 25) and measured according to AOAC (2004) method. From each storage container, 5 g of tomato sample was weighed using an electric weighing balance, 5 ml of distilled water was measured with glass measuring cylinder then pounded into juice using ceramic mortar and pestle. The juice obtained was poured into small containers. After 30 minutes, pH electrode was washed twice with distilled water and dipped into each tomato juice sample and pH value was recorded.

Ash Content

Ash content determination was based on AOAC (2004) method. Sliced tomato (2 g) was placed in crucible, heated and incinerated in a muffle furnace at 100°C for 24 hours until the contents were completely charred. The crucible was then cooled in a

desiccator and weighed. The ash content was calculated using the formula:

$$\frac{\text{Wt. of crucible and ash} - \text{Wt. of crucible}}{(\text{Wt. of crucible and sample} - \text{Wt. of crucible})} \times 100$$

Colour of the tomato fruits

A WR series colorimeter (ZL201220621866.6) was used to measure colour parameters of tomato sample and variation in colour properties was expressed in terms of Commission Internationale d'Eclairage CIE-Lab parameters (Chayjan and Alaei, 2016). Snapshots were taken in triplicates (Open, Round and Close) and read directly from the digital print, colour values were expressed as L* (darkness or lightness), a* (reddish or greenish), b* (yellowness or blueness).

Weight Loss

The weight of the tomato samples in the different storage containers was measured at the beginning and end of the experiment using electrical weighing balance. The total weight loss was taken as the difference between the initial and final weight of the tomato during the storage interval. The percentage weight loss of tomato fruits from each storage container was calculated using the following formula (Baninaiem *et al.*, 2016):

Weight loss (%) =

$$\frac{\text{Initial weight of tomato} - \text{final weight of tomato}}{\text{Initial weight of tomato}} \times 100$$

Data Analysis

Data collected on dry matter, moisture content, pH, total ash content, colour and weight loss were subjected to Analysis of Variance (ANOVA), multiple comparison of means was conducted to separate the means of significant effects including control using Tukey's Honestly Significant difference at the 5% level of significance. All data

analysis was done using the R software (V4.3.1).

RESULTS

Table 1 shows the effects of storage period on properties of stored tomato fruits at the beginning of experiment and end of the experiment. There was no significant ($p > 0.05$) difference in the mean values of dry matter at one and seven days after storage. Dry matter recorded at the beginning of experiment (7.14%) was not significantly different from the value recorded at the end of seven days after storage (7.44%). Similarly, there was no significant difference ($p > 0.05$) in moisture content, at the initial (92.90 %) and at the end of seven days after storage (92.56%). The total ash content at the beginning of experiment (1.90%) was significantly different from the value recorded at seven days after storage (1.32%), it decreased as the number of storage days increased. Also, pH of the tomato fruits at the beginning of experiment was significantly ($p < 0.05$) different from the pH value recorded at the end of seven days storage period (4.45), pH increase indicated a significant shift towards less acidity.

Table 1: Effects of storage period on postharvest properties of stored tomato fruits

Period (days)	DM (%)	MC (%)	TAC (%)	pH
1	7.17a	92.90a	1.90a	1.09b
7	7.44a	92.56a	1.32b	4.45a

DM = Dry Matter; MC = Moisture Content; TAC = Total Ash Content; pH = Potential of Hydrogen. Mean values in the same column followed by same letter(s) are not significantly different at 5% level of significance according to Tukey's Honestly Significant Difference test (Tukey's HSD).

Table 2 shows the effects of storage containers on properties of stored tomato fruits. A significant difference in dry matter values was observed for tomato fruits stored in different containers. Tomato fruits stored in raffia basket had significantly ($p < 0.05$) higher dry matter content than plastic bowl and Ziploc bag. There was no significant difference ($p > 0.05$) in dry matter content of tomato fruits stored in plastic bowl and Ziploc bag at seven days after storage.

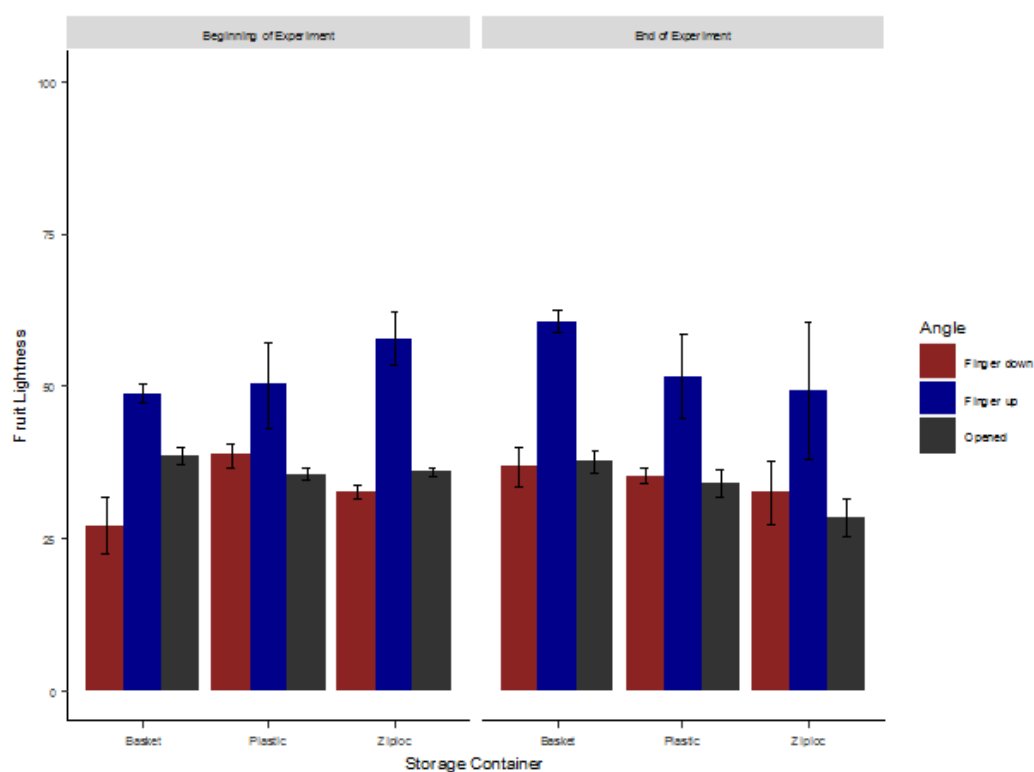
The result on moisture content of tomato fruits stored in the different storage containers showed a significant difference ($p < 0.05$) between the fruits stored in raffia baskets, plastic bowls and Ziploc bags. Significantly higher moisture content was recorded in the fruits stored in plastic bowls and Ziploc bags than raffia baskets. Tomato fruits stored in raffia baskets and plastic bowls had the least and highest moisture content, respectively. There was no significant ($p > 0.05$) difference in total ash content of tomato fruits stored in the different storage containers after seven days of storage. Nevertheless, there was no significant ($p > 0.05$) difference in the pH values of the tomato fruits stored in raffia baskets, plastic bowls and Ziploc bags.

Table 2 shows the effects of storage containers on percentage weight loss of tomato fruits after seven days of storage. There was significant difference in the weight loss of tomato fruits stored in raffia baskets compared with plastic bowls and Ziploc bags. It was observed that the effect of storage containers on weight loss of tomato fruits was significant ($p < 0.05$) between raffia baskets and Ziploc bags but not significant between plastic bowls and Ziploc bags.

Table 2: Effects of storage containers on postharvest properties of tomato fruits

Storage container	Dry matter (%)	Moisture content (%)	Total ash content	pH	Weight loss (%)
Raffia basket	7.96a	92.13b	1.31a	2.57a	19.85b
Plastic bowl	6.93b	93.07a	1.93a	2.65a	27.46a
Ziploc bag	7.03b	92.97a	1.60a	3.10a	29.53a

DM = Dry Matter; MC = Moisture Content; TAC = Total Ash Content; pH = Potential of Hydrogen. Mean values in the same column followed by same letter(s) are not significantly different at 5% level of significance according to Tukey's Honestly Significant Difference test (Tukey's HSD)

**Fig. 1:** Effects of storage containers and period of storage on tomato fruit lightness. (Each bar represents the mean values of the replicates)

This study showed that at one day of storage, higher lightness value was observed on tomato fruits stored in Ziploc bags with an open angle, followed by the fruits stored in raffia baskets at the same angle. The lowest lightness value was recorded in the tomato samples stored in raffia baskets at a closed angle. At seven days of storage, tomato fruits

stored in raffia baskets at an open angle had the highest fruit lightness while the least fruit lightness was recorded in the sample stored in Ziploc bags at round ball angle. There was no significant ($p > 0.05$) difference on the effect of storage period on the fruit lightness with an initial value of 40.50 and final value of 40.61. However, the highest fruit lightness

value (41.49) was recorded in fruits stored in raffia baskets followed by plastic bowls (40.81) and the least value (39.36) was recorded in tomato fruits stored in Ziploc bags.

Generally, considering both factors with respect to angle, as shown in Fig. 1, there

was no significant difference ($p>0.05$) between effect of round ball and closed angles on stored tomato fruit lightness with values of 34.98 and 33.76 respectively. However, there was a significant difference between open angle (52.92) and the two other angles.

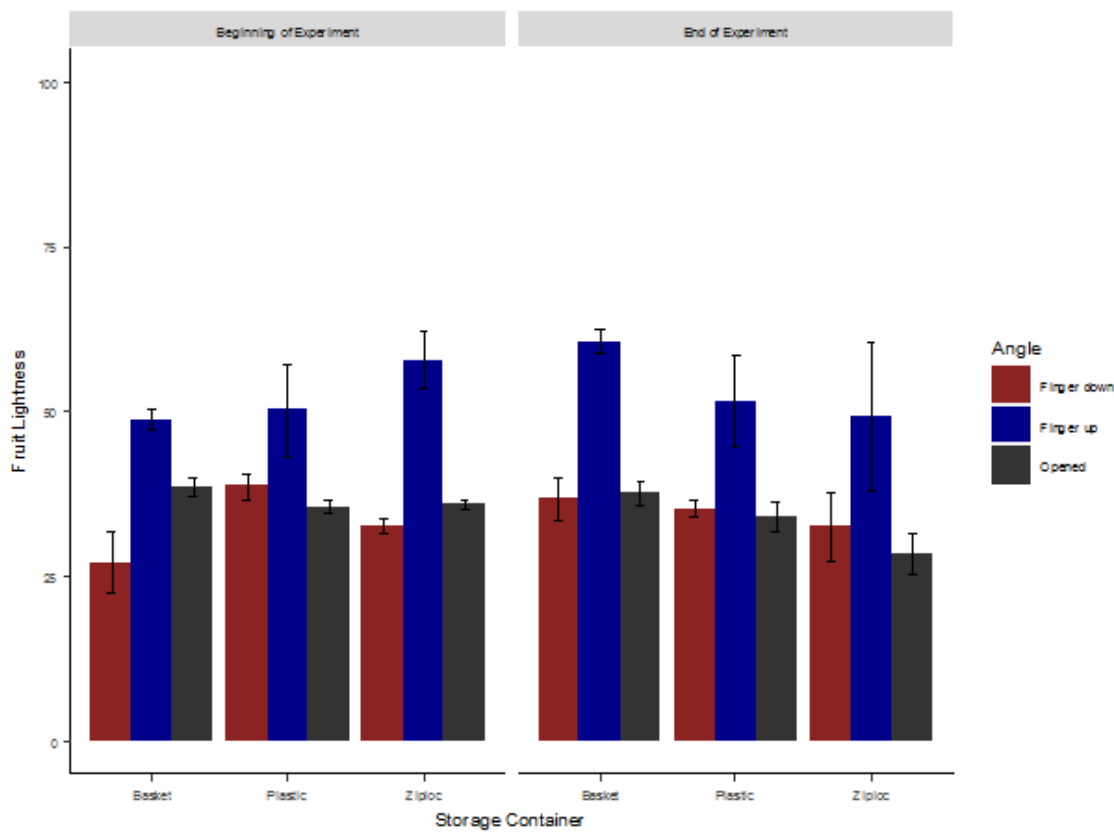


Fig. 2: Effects of storage container and storage period on tomato fruits redness. (Each bar represents the mean values of the replicates.)

It was observed that at the beginning of experiment, the highest intensity of redness was recorded in tomato fruits stored in Ziploc bags with a closed angle followed by tomato fruits stored in plastic bowls at the same angle. The fruits stored in raffia baskets at an open angle had the lowest redness

value. At the end of the experiment, the maximum level of fruit redness was recorded in tomato fruits stored in Ziploc bags at round ball angle, the lowest value was achieved on the fruits stored in raffia baskets at open angle. Effect of storage period had no significant ($p>0.05$) difference on tomato

fruit redness with an initial value of 22.91 and final value of 23.42.

From Fig. 2, there was no significant ($p>0.05$) difference in how the storage containers affected the tomato fruits that were being stored. However, tomato fruit stored in plastic bowls had the highest value (25.47) followed by the fruits in Ziploc bags (23.73) and those stored in raffia baskets (20.30).

When both parameters (storage period and containers) were taken into account with regard to angle, no significant difference was found between the influence of round ball (26.81) and closed angles (28.14) on the redness of stored tomato fruit ($p>0.05$). Open angle (14.55), however, differed significantly ($p>0.05$) from the other two.

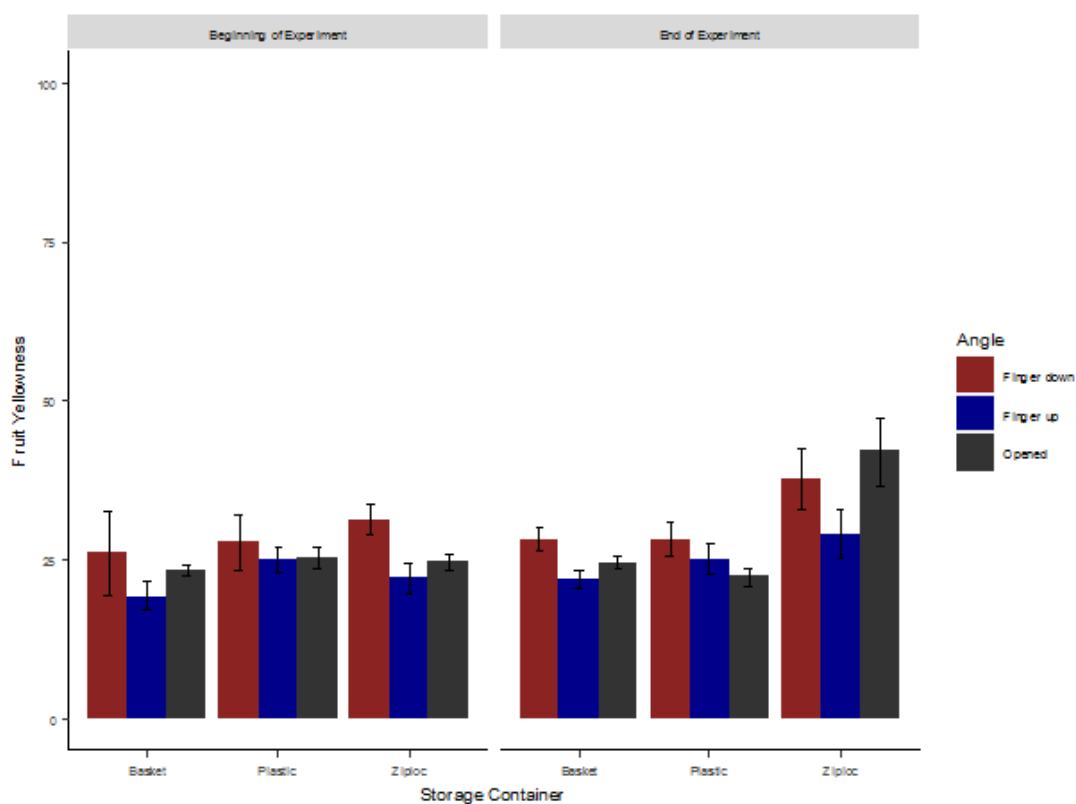


Fig. 3: Effects of storage containers and period on tomato fruits yellowness. (Each bar represents the mean value of the replicates)

Fig. 3 shows the effect of storage containers and period on tomato fruits with respect to yellowness. At the initial stage of the experiment, the tomato fruits stored in Ziploc bags at a closed angle recorded the maximum level of yellowness, and fruits stored in plastic bowls proceeded at the same angle

while the minimum level of yellowness was in the fruits stored in raffia basket at open angle.

At the end of the experiment, the highest level of yellowness was observed in fruits stored in Ziploc bags at round ball angle

while the lowest level was in tomato fruits stored in raffia baskets at an open angle. There was no significant ($p>0.05$) difference on effect of storage period on tomato fruit yellowness which recorded an initial value of 24.95 and final value of 28.74.

There was no significant difference ($p>0.05$) between the effects of storage containers on the stored tomato fruits. However, tomato fruits stored in Ziploc bags had the highest value (31.10), while the fruits stored in raffia basket had the lowest value (23.87) and the mid value was recorded for fruits stored in plastic bowls (25.57). This showed that the effect of Ziploc bags on stored tomato was significant.

From Fig. 3, there was no significant ($p>0.05$) difference between round ball (26.98), closed (29.84) and open (23.72) angles when both factors (storage containers and period) were taken into account with regard to colour of stored tomato fruit. Nevertheless, there was a significant ($p<0.05$) difference between closed and open angles as shown in Fig. 3.

DISCUSSION

Dry matter reflects the solid content of tomato fruits and is inversely related to moisture content. Dry matter content in fruits is an indication of the sugar content and its presence in high concentration gives the fruit a good taste. In this study, the dry matter content in the sampled tomato fruits increased with storage duration. Veringa *et al.* (2023) revealed that the dry matter content increased slightly for all storage conditions, with refrigeration recording more pronounced increase. Moisture loss in fruits leads to shrivel or wrinkle, causing them to lose their refreshing character and making them unattractive in appearance. Moisture content decreased in the stored tomato fruits

which was in agreement with the increase in moisture loss at ambient conditions after 14 days of storage reported by Khalid *et al.* (2022). Loss of moisture is mainly attributed to water evaporation and enzymatic breakdown of cellular structures. An important goal of postharvest handling is to keep the product cool to avoid moisture loss, slow down undesirable chemical changes, and to avoid physical damages (El-Ramady *et al.*, 2015). Moisture loss was greater in the sample stored in raffia basket than Ziploc bag and plastic bowl. Ash content is a good source of potassium (K), calcium (Ca), phosphorus (P) and magnesium (Mg), these macronutrients ensure safety of fruits. Ash content also enables the determination of the amount and type of minerals in the fruit. The amount of minerals can determine physicochemical properties of the fruit as well as retard the growth of microorganisms. Ash content was higher in plastic container and lower in raffia basket. However, the tomato fruits in plastic bowls retained ash content better than the fruits stored in raffia baskets and Ziploc bags. Tomato fruits stored in plastic bowls gave results that were comparable to other containers in terms of ash content. A study by Singh and Sharma (2018) reported a gradual decrease in the total ash content of tomatoes during extended storage. The result of ash content from this study was not in agreement with the result of Oladipupo *et al.* (2020) that recorded slight increase in all packaging materials during the 6 weeks period of storage.

The shelf life and inhibition of multiplication of microorganisms in fruits can be prolonged given the adequate pH values. Higher pH values in fruits could be as a result of ripening and damages. Tomato fruit ripening processes causes its pH to rise due to the conversion of acids to sugars by gluconeogenesis (Anthon *et al.*, 2011). The

increase in pH values recorded from the three storage containers was in agreement with the findings of Adhikari *et al.* (2020) who revealed that the pH value of tomatoes increases with the storage time due to ripening and respiration. Dladla and Workneh (2023) revealed that unpackaged (control) tomatoes had the highest increase in pH value from 4.20 to 4.60 under ambient storage conditions. Islam *et al.* (2013) also reported an increase in pH of tomato fruits with maturity and mango fruits during storage, respectively. The rise in pH can be linked to the breakdown of organic acids and the accumulation of basic compounds. Azene *et al.* (2014) posited that higher pH values of tomatoes under ambient storage conditions could be attributed to the faster conversion rate of acids to sugar, due to the rapid rate of respiration experienced by tomatoes during ripening. In this study, tomato fruits stored in raffia baskets resulted in a non-significant lower pH value compared with those stored in plastic bowl and Ziploc bag.

Colour is an important sense of vision, which is also considered in relation with antioxidant capacity of fruits and vegetables. Total colour change after storage was considered in this study because of changes in L*, a* and b* (lightness, redness and yellowness) values. Storage containers had no significant effect on L* values in this study. This result agreed with the findings of Al-Dairi and Pathare (2021) for tomato stored for 10 days at 10°C, but differed from the results of the study carried out by Saad *et al.* (2016) where the values of L* decreased slightly during ripening stages, reflecting darkening of tomatoes with carotenoid synthesis and loss of greenness. Effect of storage containers on a* value (redness) of the tomato fruit was not significant in this study with, the highest value recorded in the sample stored in plastic bowls, the minimum value was observed in

samples stored in raffia baskets. Zou *et al.* (2018) reported high rapid red color development in cherry tomatoes stored at 25°C compared to 10°C and 4°C after 28 days storage period. Munhewyi (2012) reported that tomato fruits stored at ambient temperatures can provide an excellent setting for tomato ripening, which is characterized by rising redness. Park *et al.* (2018) revealed that mature tomatoes stored for 20 days at 20°C had the same behaviour. Al-Dairi and Pathare (2021) reported no significant differences ($p > 0.05$) on b* value of fresh tomato during storage period of 12 days at 10°C and 22°C. Regarding the effect of storage containers on b* (yellowness) of tomato fruit, the highest value was observed on tomato fruit stored in Ziploc bags, indicating that chromaticity values and parameters changed after storage which could be as a result of the process of ripening as suggested by Saad *et al.* (2016).

Asem *et al.* (2016) stated that the permeability properties of the storage structure generate a localized modified atmosphere inside the structure, which can be negative or positive, depending on the response of the fruit to its new surrounding atmospheric conditions. Weight loss is known to be the major determinant of storage life and quality of fresh commodities. Higher temperatures accelerate the rate of transpiration and enhance water loss, causing the fruits to wrinkle, contract and soften. This explains the increasing trend of water loss in tomato fruits stored in closed containers at ambient temperature. At ambient storage condition, low relative humidity reduces the amount of water in the fresh produce resulting in weight reduction (Ayomide *et al.*, 2019). The variance in physiological processes and responses to atmospheric condition between tomato fruits stored in different storage containers could be the

cause of the variation in the rate of weight loss of tomato fruits. Pérez *et al.* (2016) reported that weight loss of most fruits and vegetables during storage depends on the temperature and relative humidity conditions. Weight loss of tomato was minimum in the samples stored in raffia basket after seven days of storage. Tomato fruits stored in Ziploc bags and raffia baskets softened quickly and the texture became mushy, the overall appearance and colour deteriorated which later resulted to white mould growth, decay and unpleasant odour whereas the ones stored in plastic bowls were firm seven days after storage. The buildup of free water on the fruit's surfaces could result from the loss of water through transpiration and respiration, giving pathogens a favourable environment for growth and caused the tomato fruit to deteriorate. Ahmed *et al.* (2016) reported that tissue maceration due to pathogen leads to progressive deterioration. The skin thickness of tomato fruit may be related to how quickly the fruit loses weight. According to Wills *et al.* (2016), the thickness of the pericarp or peel has a direct bearing on the pace at which water evaporates from fruit, causing a wilted rind and shriveled look. Modification of the storage conditions surrounding the tomato fruit, such as storage containers and atmosphere, could minimize the rate of transpiration and respiration of the fruits.

CONCLUSION

Storage containers plays a significant role in retaining the properties of tomato for the period of storage. It was observed that the tomato stored in the plastic bowls retained more moisture and suffered the least damage from deterioration followed by Ziploc bags and raffia baskets. Therefore, it is recommended that tomato fruits be stored in plastic bowls to improve the shelf life.

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