Effect of Different Storage Structures and Duration of Time on Some Postharvest Qualities of Tomato (Lycopersiconesculentum Mill.)

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Abstract: The rapid quality loss of tomatoes at relatively short period of 4-7 days after harvest requires an efficient means of storing the fruits to reduce postharvest losses. This study therefore evaluated the influence of three different storage structures: Refrigerator (10°C and 40-45% Relative Humidity), Evaporative coolant structure (ECS) (26°C and 58-62% Relative Humidity) and open shelf (28.8°C and 70-75% Relative Humidity) on the postharvest quality of mature green tomatoes (San Marzano variety) stored for 34 days. Data was collected on firmness, disease incidence and overall freshness of the stored tomatoes fruits at interval of 3 days using a subjective scale. Proximate analysis to determine Titratable Acidity (TA), Total Soluble Solids (TSS) and Vitamin C content of fruits was also conducted at the green, light red, deep red ripening stages and at deterioration of fruits. Data collected were subjected to analysis of variance and significantly different means were separated using least significant difference at 0.05% level of probability. There was no significant difference in the postharvest physical qualities (firmness, disease incidence and overall freshness) of the stored tomatoes in the three storage structures at the first 9 days of storage. At 27 days after storage the tomatoes fruits stored in the ECS had the least firmness (4.33), freshness (0.67) and the highest disease incidence (3.33) which was significantly lower than the value obtained from the tomatoes stored in the refrigerator and open shelf. Chilling injury was observed on tomatoes stored in the refrigerator at 27 days after storage which led to significantly lower tomatoes fruit quality at 34 days after storage when compared with the open shelf. As ripening progressed it was observed that TSS of the stored tomatoes fruits increased across the three storage conditions while the TA of the fruits declined. The Vitamin C content of tomatoes increased as ripening progressed but decreased at deterioration with ECS giving the highest Vitamin C content (28.37 mg/100g) of stored tomatoes fruits at deterioration among the refrigerator, evaporative coolant structure and open shelf, the ECS gave the best postharvest chemical properties of fruits at deterioration. The order of preservation with reference to number of days in storage is open shelf > Refrigerator > ECS.

I. Introduction

Tomato (Lycopersiconesculentum Mill.) originated from South America and belongs to the family solanaceae. It is considered as an important food and cash crop in many parts of the world which also serves as raw material for production of value added products by food industry ¹, ². It is consumed either fresh as salad or after processing into pastes or puree which is used for cooking and in the production of fruit drinks and ketchup ³. ⁴. High quality tomatoes have a firm turgid appearance, uniform and shiny color, without sign of mechanical injuries, shriveling or decay ⁵.

Nigeria has the largest area harvested for fresh tomatoes in Africa with 541,800 Ha and yield of 4.0MT/Ha ⁶. However, 45% of the tomatoes produced in the country is estimated as annual loss due to poor processing technology, lack of good storage system and the transport system used for the distribution of fresh tomatoes ⁷, ⁸. It is distressing to know that many resources is devoted to planting the crop, irrigation, fertilizer application and crop protection management only to be wasted in few days after harvest ⁹. Postharvest losses in tomatoes cannot be eliminated, but can be reduced within certain limits by applying appropriate postharvest technology ⁹.

Some authors ¹⁰ reiterated that the properties, quality and nutritional value of fresh produce is affected by postharvest handling and storage condition. An author ¹¹ submitted that loss of vitamins, especially ascorbic acid (vitamin C), during storage adversely affects nutritional quality of the produce. In Nigeria, tomatoes are harvested at vine-ripe due to lack of cool-chain and ripening facilities to handle mature-green tomatoes to turning stages ¹². However when harvested at the mature green stage, all tomatoes cultivar have the longest shelf-life and shelf-life is the most important aspect in loss reduction biotechnology of fruit and vegetables ¹³, ¹⁴.

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An author\textsuperscript{15} reported that an increasing demand for produce with excellent quality and extended shelf-life had made postharvest quality more and more important together with the optimization of storage structures. Thus, sequel to the high postharvest loss of tomatoes, extension of the shelf-life of the fruits by harvesting at the mature green stage necessitates the use of available storage structure for ripening. Erratic power supply and low income of rural farmers makes refrigerator expensive\textsuperscript{16}. The evaluation of the influence of low cost cooling system such as the evaporative coolant structure on the physical and chemical properties of stored tomatoes at some ripening stages and deterioration becomes paramount due to the increased interest of consumer in the quality of produce. The objectives of this study are therefore to evaluate the effect of different storage structures on the physical, chemical properties and shelf-life extension of green tomatoes.

**II. Material And Methods**

The experiment was conducted at the Department of Agronomy, University of Ibadan, Ibadan, Oyo state between October to November, 2014.

**Source of Experimental Materials:** Mature green tomatoes (San Marzano variety) obtained from a commercial farm at Ibadan.

**Samples Preparation for Storage:** The tomatoes were sorted to ensure they were free of spots and bruise, disinfected by dipping in a fungicide solution and subsequently drained and air dried. The tomatoes fruits were weighed and packaged in perforated polyethylene bags.

**Experimental Design:** Completely randomized design with three replicates.

**Storage Experiment:** The packaged tomatoes fruits were arranged in the following storage structures;

- The refrigerator (10°C) and (40% - 45% Relative Humidity)
- The evaporative coolant structure (26°C) and (70% - 75% Relative Humidity)
- The open shelf (control) (28.8°C) and (58% - 62% Relative Humidity)

**Construction and Principle of Operation of the Pot-in-Pot Evaporative coolant structure**

This was constructed by coating the outside of a burnt clay pot (that is about 65 cm high and has wall thickness of about 8mm) with cement. The pot is placed inside another slightly bigger pot leaving a space of about 7 cm between the two. The space between the two pots is filled with riverbed sand which is kept moist by watering frequently. A perforated plastic sieve was placed at the base of the inner pot and the tomatoes were stored in the inner pot while the clay pot is provided with a suitable cover. The structure was placed on a metallic suitable tripod stand under a constructed shed, where there was free air movement for evaporation of water.

**Figure 1:** The Pot-in-Pot Evaporative Coolant Structure (26°C)

An author\textsuperscript{16} described the principle underlying evaporative cooling as the conversion of sensible heat to latent heat. The warm and dry outdoor air is forced through porous wall or wetted pads that are replenished with water from the cooler’s reservoir. Due to the low humidity of the incoming air, some of the water evaporated. Some of the sensible heat of the air is transferred to the water and becomes latent heat by evaporating some of the water. The latent heat follows the water vapour and diffuses into the air. Evaporation causes a drop in the dry-bulb temperature and a rise in the relative humidity of the air in the inner pot.
Data Collection: Data were taken at three days interval on physical parameters of firmness, disease incidence and overall freshness of the tomatoes fruits during the storage period. While the proximate analysis of tomato fruits to determine the Vitamin C, Titrable acidity and total soluble solids content of the fruits was done at the green, light red and deep red ripening stages as well as at deterioration.

Firmness: This is determined by hand feel and the result was rated on a subjective scale as follows; 5 = Not firm, 4 = Slightly firm, 3 = Moderately firm, 2 = Firm, 1 = Very firm

Disease incidence: This was evaluated through visual observation of tomato fruits at interval of three days for noticeable skin defects, blemishes and mould growth using a subjective scale of 1 - 4 where 1 = wholesome, 2 = slightly infected, 3 = moderately infected and 4 = highly infected

Freshness: The overall freshness of the fruits was evaluated by using a scale of 0 - 4 in line with the method of IPGRI/IITA (1998), where 4 = excellent; 3 = good; 2 = acceptable; 1 = unacceptable and 0 = poor.

Determination of Titratable Acidity: The sample was transferred into 250 ml conical flask. 4-5 drops of phenolphthalein indicator was added and 25 ml burette was filled with 0.1N Sodium hydroxide. The sample mixture was titrated with the 0.1N Sodium hydroxide until the indicator just turns pink/red. The titre volume of the Sodium Hydroxide that was added was recorded. The calculation of the titratable Acidity was done by dividing the titre value obtained by 10.

Determination of Total soluble solids: 4 gram of sample was weigh and blended with 39 ml water. The tomato suspension was filtered through Whatman No.1 filter paper. The filtrate was put into a weighed petri dish and was evaporated to dryness. The petri dish was weighed to get the weight of dried soluble matter. The weight of dried soluble matter was put over weight of sample taken times 100.

Determination of Ascorbic Acid Content: 0.05 g of 2:6 Dichlorophenol was dissolved in water. It was diluted to 100 ml and standardized. 0.05 g pure ascorbic acid was dissolved in 600 ml of 20 % Meta phosphoric acid and diluted with water to exactly 250 ml. 10 ml of this solution was pipette into small flask and titrated with the Indophenol solution until a faint pink colour persists for fifteen seconds. The concentration was expressed as mg. ascorbic acid equivalent to 1.0 ml of the dye solution. Sample was macerated in a mortar and filtered through a nylon cloth. 25.0ml was pipette into a 50 ml flask and 12 ml of 20 % Meta phosphoric acid was added and the mixture was diluted with water to 50 ml. 10 ml of this solution was pipette into a small flask and titrated with the 2:6 Dichlorophenol Indophenol solution. Calculation of the Vitamin C was done as mg. per 100 ml of juice.

Statistical analysis: All data collected were subjected to analysis of variance and significantly different means were separated using least significant difference at 0.05% level of probability.

III. Result

Effect of storage conditions on firmness

The result on Figure 2 shows that no significant (P<0.05) difference was observed in firmness of the tomatoes in the three storage conditions during the first 12 days of storage. However, from 15 to 27 days length of storage, the evaporative coolant structure recorded the least firmness of tomatoes fruits (with average scores that ranged from 2.7 to 4.3 i.e. moderately firm to slightly firm) which were significantly (P<0.05) lower than the refrigerator (with mean scores from 1.3 to 3.0 i.e. very firm to moderately firm) and open shelf (2.0 i.e. firm) with the exception of the 15 days length of storage when it had firmness score 2.7 i.e. moderately firm that was not significantly (P<0.05) different from the open shelf (2.0 i.e. firm). At 34 days length of storage the best firmness was observed in the open shelf (2.3 i.e. firm) which was significantly (P<0.05) better than the refrigerator (3.3 i.e. moderately firm).
Effect of Different Storage Structures and Duration of Time on Some Postharvest Qualities

Effect of storage conditions on disease incidence

The results on Figure 3 shows that during the first 12 days of storage, there was no significant (P<0.05) difference among the three storage conditions with respect to disease incidence. The evaporative coolant structure however had the highest incidence of disease (with average scores of 1.7 to 3.3) from 15 to 27 days length of storage which was significantly (P<0.05) higher than that observed in the open shelf (with mean scores of 1.0 to 2.0) and refrigerator (with mean scores of 1.0 to 2.0) during this storage period. At 34 days length of storage the least disease incidence was observed in the open shelf (2.0) which was significantly (P<0.05) lower than that observed in the refrigerator (3.0).

Effect of storage conditions on freshness of tomatoes

The result on Figure 4 shows that there was no significant (P<0.05) difference in freshness among the three storage conditions for the first 6 days after storage. From 12 to 27 days length of storage the refrigerator had the best fruit freshness with average score of 4.0 to 3.0 (i.e. excellent to good) which was significantly (P<0.05) better than the evaporative coolant structure (with average scores of 3.0 to 0.7) and open shelf (with average scores of 3.3 to 3.0) with the exception of 24 and 27 days length of storage when it had average freshness score of 3.3 (good) and 3.0(good) respectively which were not significantly (P<0.05) different from the open shelf with mean score of 3.0 (i.e. good appearance). The open shelf however had a better fruit freshness mean score of 3.0 at 31 and 34 days length of storage, which was significantly (P< 0.05) better than the refrigerators with freshness mean score of 2.0.
Effect of storage conditions on Vitamin C (mg/100g) content of tomatoes at some ripening stages and deterioration

The result on Table no1 shows that at the light red stage, the vitamin C content of tomatoes increased from the initial 28.77 mg/100g obtained at the green stage across all the three storage conditions with the evaporative coolant structure giving the highest vitamin C content of 33.57 mg/100g which was significantly (P<0.05) higher than the refrigerator (32.40 mg/100g) and open shelf (29.77mg/100g) at this ripening stage. However at the deep red stage, the vitamin C content of the refrigerator and open shelf further increased with refrigerator giving the highest vitamin C value of 35.37 mg/100g which was significantly (P<0.05) higher than the open shelf 32.84 mg/100 and the evaporative coolant structure which decreased to 25.77 mg/100g at this stage of ripening. At deterioration the vitamin C content of the open shelf and refrigerator however decreased with the open shelf giving the lowest vitamin C content of 23.83 mg/100g which was significantly (P<0.05) lower than the evaporative coolant structure (28.37 mg/100g) and refrigerator (24.53 mg/100g).

Figure 4: Effect of storage conditions on overall freshness

Table no1: Effect of storage conditions on Vitamin C (mg/100g) content of tomatoes at some ripening stages and deterioration.

<table>
<thead>
<tr>
<th>Storage Structures</th>
<th>Ripening Stages (Vitamin C (mg/100g))</th>
<th>Green Stage</th>
<th>Light Red Stage</th>
<th>Deep Red Stage</th>
<th>Deterioration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td></td>
<td>28.77</td>
<td>32.40</td>
<td>35.37</td>
<td>24.53</td>
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<tr>
<td>ECS</td>
<td></td>
<td>28.77</td>
<td>33.57</td>
<td>25.77</td>
<td>28.37</td>
</tr>
<tr>
<td>Open Shelf</td>
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<td>28.77</td>
<td>29.77</td>
<td>32.84</td>
<td>23.83</td>
</tr>
<tr>
<td>Lsd (P&lt;0.05)</td>
<td></td>
<td>Ns</td>
<td>0.48</td>
<td>0.42</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Effect of storage conditions on Total Soluble Solids (%) of tomatoes at some ripening stages and deterioration

The total soluble solids increased across the ripening stages towards deterioration in all the three storage conditions with the exception of evaporative coolant structure which gave a decreased total soluble solids of 42.97 % at deterioration which was significantly (P<0.05) lower than the refrigerator (45.57 %) and open shelf (43.83 %) when compared with the value of 43.33 % obtained in the ECS at the deep red stage of ripening (Table no2). The three storage conditions were however significantly (P<0.05) different from each other across all the ripening stages with the exception of the light red stage when the refrigeration had total soluble solids of 38.63 % that was not significantly (P<0.05) different from the open shelf (38.37 %).

Effect of storage conditions on Titrable Acidity (T/10) of tomatoes at some ripening stages and deterioration

The titrable acidity decreased from the green stage to the deep red ripening stage in all the three storage conditions with the exception of the evaporative coolant structure which gave a titrable acidity value of 0.51 at the deep red.
stage which was higher than the 0.44 titratable acidity value observed at the light red stage of ripening (Table no3). However the titratable acidity of the tomatoes under the three storage conditions increased at deterioration with the refrigerator having the highest titratable acidity of (0.57) which was significantly (P<0.05) higher than the open shelf (0.52) and evaporative coolant structure (0.54).

Table no3: Effect of storage conditions on the Titratable Acidity (T/10) of tomatoes at some ripening stages and deterioration

<table>
<thead>
<tr>
<th>Storage Conditions</th>
<th>Ripening Stages (Titratable Acidity (T/10))</th>
<th>Green Stage</th>
<th>Light Red Stage</th>
<th>Deep Red Stage</th>
<th>Deterioration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td></td>
<td>0.72</td>
<td>0.44</td>
<td>0.51</td>
<td>0.54</td>
</tr>
<tr>
<td>ECS</td>
<td></td>
<td>0.72</td>
<td>0.44</td>
<td>0.51</td>
<td>0.54</td>
</tr>
<tr>
<td>Open shelf</td>
<td></td>
<td>0.72</td>
<td>0.49</td>
<td>0.46</td>
<td>0.52</td>
</tr>
<tr>
<td>LSD (P&lt;0.05)</td>
<td></td>
<td>Ns</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The observation of reduction in tomatoes fruit firmness with the passage of time in storage is in line with the submission of some authors17 who reported that the fruit firmness of some tomatoes varieties decreased with time in different storage conditions except in the deep freezer. This decrease in fruits firmness is caused by the softening of fruits which results from the remodeling and degradation of the cell wall that occurred during ripening18, 19, 20. The highest softening of fruits and subsequent loss of firmness in the ECS can be attributed to the cooking of fruit by the heat of respiration and water droplet trapped in the polyethylene bags that was used for packaging. However, the occurrence of chilling injury at 27 days of storage of tomatoes in the refrigerator led to softening of fruits and subsequent reduction in firmness. This confirms the observation of some authors21, 22 that tomatoes cannot be stored in the domestic refrigerator for a long period as they are susceptible to chilling injury. The maintenance of firmness in the open shelf was due to the removal of heat of respiration by the Free air which flows around produce23.

Disease incidence is observed on fruits when spots, blemishes, mould growth and other abnormities are observed on fruits. The result (Figure 3) showed that the three storage structures can prevent disease incidence on tomatoes fruits to the same extents up to 12 days of storage. The high disease incidence observed in the evaporative coolant structure from 15 to 27 days of storage might be attributed to high relative humidity, poor ventilation (which led to carbon dioxide accumulation around the produce), and increasing moisture loss from fruit which is accumulated within the polyethylene bag during this storage period. Some authors24 reported that bacteria which is one of the major disease causing organism can rapidly multiply and spread, particularly in water even on thin coating of water, such as on a wet fruit. The onset of chilling injury in the refrigerator which was observed on 27th day of storage made the fruit susceptible to attacks by psychrophilic microorganism which resulted to disease incidence25. Accumulation of water on fruit when electric power supply fails combined with the increase in temperature during such period of storage provides a conducive environment for the proliferation of disease causing organism. The same author25 also stated that refrigerated tomatoes can be ruined by the growth of psychrophilic microorganism. An author26 also explained that the presence of bacteria, yeast, and mold can have an adverse impact upon refrigerated products. Lower disease incidence of 2.3 (slightly infected) was however observed in the open shelf at 34 days after storage which was significantly (P<0.05) lower than the refrigerator (3.0 i.e. moderately infected). In Nigeria the higher disease incidence that is always observed in the open shelf during the postharvest chain is due to exposure of tomatoes to direct sunshine, poor postharvest handling and reuse of traditional weaved wicker baskets for packaging tomatoes until the baskets becomes infected with primary fungal spores from previously infected fruits. These pathogenic inocula occurring on wooden boxes and baskets can initiate disease upon contact with healthy fruits, which eventually result to losses27.

The overall freshness of a produce depends on the extent of changes that occurs in it quality parameter during the process of storage. The major problem during storage is the change in the quality parameters of the
produce especially the physical characteristics such as; the color, texture, and freshness. Generally, the loss of freshness of perishable commodities depends on the rate of respiration. The reduction in tomatoes freshness from the 9th day of storage which increased with increasing length of storage towards deterioration and storage conditions validated the assertion of some authors that deterioration of fresh commodities can result from physiological break down due to natural processes, water loss, temperature injury, physiological damage or invasion by microorganisms and that all these can interact and are influenced by temperature. The highest freshness of tomatoes fruits of 4.0 (excellent appearance) observed in the refrigerator from 12 days after storage to 21 days after storage which was significantly (P<0.05) higher than the open shelf and evaporative coolant structure can be attributed to the low temperature in the refrigerator which slowed down all processes that can lead to rapid physiological break down of fruit and hence minimized deterioration of fruits with the passage of time. This result also agrees with the submission of some authors that the refrigerator creates a high humid environment for the stored produce that slows the rate of moisture loss, metabolic activities and the activities of micro-organisms (pathogens) which are the most destructive activity during storage of fruits and vegetables. In another development, an author also reported that fruits storage at extremely low temperature preserves quality better at increased storage period. At 34 days of storage, the open shelf was however observed to have freshness of 3 (good appearance) that was significantly (P< 0.05) better than the refrigerator which had a freshness score of 2 (acceptable freshness).

The result (Table no1) showing the increase in vitamin C content of open shelf and refrigerator from the green stage to the red deep stage is in line with the observation some authors who reiterated that during storage, it is noticed that ascorbic acid increased first with the ripening stage from light pink stage to red stage of ripening after this it decreased with the increase in red color and storage time. Preservation of ascorbic acid content during storage is however a difficult task since it undergoes oxidation. Thus the observed reduction of the vitamin C content of the refrigerator and open shelf at deterioration. The lowest vitamin C content observed in the open shelf (23.83 mg/100g) at deterioration was due to the presence of higher oxygen concentrations in the storage atmosphere which hastens this process. Since vitamin C is easily oxidized, storage and the cooking in air leads to the eventual oxidation of vitamin C by oxygen in the atmosphere. Also according to two authors, increased temperatures normally results in high percentage loss of ascorbic acid. The highest mean temperature recorded in the open shelf might also be responsible for this reduction.

The total soluble solids acts as a rough index of the amount of sugars present in fruits. It is the amount of sugar and soluble minerals present in fruits and vegetables. It was observed that the total soluble solids content of the tomatoes changed as ripening progressed towards deterioration (Table no2). This agreed with the findings of some authors who reported that during ripening, the total soluble solute content of tomato fruit changes. This change in TSS content was due to the natural phenomenon that occurred during ripening and are correlated with hydrolytic changes in starch concentration during postharvest period. In tomatoes, conversion of starch to sugar is an important index of ripening. Thus the significant increase in the total soluble solids during ripening in tomatoes stored in all the storage structures might be due to conversion of polysaccharides to simple sugars. Present observation agrees with the findings of some author who reported that total soluble solids of tomatoes increased at different ripening stages, temperatures and packaging materials. Chilling injury observed in refrigerator however accelerated the rate of polysaccharide degradation to sugar and this led to increased total soluble solids of tomatoes of refrigerator at deterioration when compared with the open shelf.

Titratable acidity is a measure of all aggregate acids and sum of all volatile and fixed acids. According to an author, acidity is often used as an indication of maturity, as acid decreases on ripening of fruit. A decreased titratable acidity was observed in the three storage conditions at the light and deep red stage of ripening when compared with the green stage. The general gradual decrease in titratable acidity of tomatoes with time during ripening and storage had been confirmed by different authors. This can be attributed to the disappearance of malic acid first, followed by citric acid which results in reduction of the amount of titratable acidity, suggesting the catabolism of citrate via malate.

### IV. Conclusion

Present observations in this study revealed that the three storage structures influence the deviation from the initial quality of tomatoes to different extent. Although the ECS preserved the nutritional composition of tomatoes better at deterioration, its higher rate of deterioration, poor postharvest physical quality preservation and low shelf life extension makes it an economic and efficient storage structure for only short term storage of tomatoes. The open shelf may therefore be a good storage method for long term storage of tomatoes provided the tomatoes are properly handled and kept away from direction of sunlight. The use of perforated plastic crates or basket is preferable to the use of woven bamboo basket which react with tomatoes to hasten spoilage especially when they are reused for a long time without disinfecting them. Further studies to validate the efficiency of the open shelf to extend the shelf-life of tomatoes and preserve it postharvest quality for long storage period should.
be conducted. Further research should also be conducted to improve the efficiency of the ECS by providing controlled ventilation for fruits.

References