

RESEARCH ARTICLE

Effects of packaging and storage conditions on quality and storage life of tomato fruits (*Lycopersicon esculentum* MILL.) in Kura, Kano State, Nigeria

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ABSTRACT

Nigeria being the second largest producer of tomatoes in Africa and 13th in the world has an estimated total postharvest loss of over 60%. This prompted search for simple cost effective methods to extend the shelf life of tomatoes. This study carried out in Kura Kano state investigates effects of packaging and storage conditions on quality and storage life of tomatoes. Green mature tomatoes were harvested early in the morning, sorted, graded and divided into 3 kg lots each. Fruits were subjected to 3 postharvest dips, packaged in 3 packages and stored under 3 conditions. Physico-chemical analyses were conducted on first day and there after every three days. Data generated were analyzed using GLM procedure of SAS and means separated using LSD. Results of combined effects of packaging and storage showed that fruits packaged in kraft paper bag and stored in zero energy cool chamber was the best combination because it maintained physico-chemical parameters of the fruits within an acceptable limit up to 21 days of storage; it also maintained the fruit quality without the problem of chilling injury which aggravates weight loss and rotting of fruits. This combination could therefore be recommended for short term storage of fresh tomato fruits.

Keywords: Firmness, Loss, Postharvest, Paper, and Tomato

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INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a herbaceous plant belonging to the family Solanaceae, which is believed to be domesticated between Mexico and West coast of South America. It was introduced to Spain in 16th century and dispersed throughout Africa by Portuguese merchants (De-Lennoy, 2001). It is a popular vegetable worldwide and plays a vital role in human diet (Sibromana et al. 2015). Tomatoes are consumed whole peeled or in salads, cooked into soups or processed into juice, ketchup, paste and puree (Adedeji et al., 2005). Tomatoes are rich source of vitamins, minerals, sugars, essential amino acids, iron, dietary fibers and phosphorus (Ayendiji et al., 2011).

Tomato fruits also contain higher amounts of lycopene, a carotenoid with anti oxidant properties beneficial in reducing incidence of chronic diseases like cancer and other cardiovascular disorders (Basu and Imrhan, 2007). Nigeria is the second largest producer of tomato fruits in Africa and 13th in the world (FAOSTAT, 2014); but estimated postharvest loss of tomato

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fruits in Nigeria is about 60% (Kutama et al., 2007) which translates to huge economic loss. The huge loss has prompted the search for simple, effective and economical method to reduce these losses in tomatoes. Postharvest technologies like chemical treatments, packaging and storage positively influence the level of postharvest losses and the quality of the produce (Srividya et al., 2014). An improvement in tomato postharvest handling, packaging and storage is really desirable. Therefore this study was aimed at investigating the combined effects of packaging and storage conditions on the quality and storability of tomato fruits in Kura, Kano State of Nigeria.

MATERIALS AND METHODS

The study was conducted at Kofar Yamma, Kura local Government of Kano State (latitude 11° 46' N and longitude 8° 25' E) between 2nd March to 27th March, 2014. The analyses were conducted in the Laboratories of the Department of Food Science and Technology, Kano University of Science and Technology Wudil and Kano area laboratory of Abuja Commodity Exchange Plc. The fruits (UC 82B grown in Kura) of fairly uniform sizes were carefully hand harvested at green mature stage. The design was a factorial design laid out in randomized complete block design (RCBD). There were three factors; postharvest treatments, packaging and storage each having 3 levels which were replicated three times. Postharvest treatments consisted of three levels which were:

- i. freshly harvested tomato fruits packaged in kraft paper bag (P_1)
- ii. freshly harvested tomato fruits packaged perforated polyethylene bag (P_2)
- iii. freshly harvested tomato fruits packaged perforated polyethylene bag (P_3)

The storage conditions consisted also of three levels which were:

- i. Storage of fresh tomato fruits at ambient room temperature (S_1) [32 °C and 29% RH]
- ii. Storage of fresh tomato fruits at refrigerated chamber (S_2) [11°C and 90-95% RH]
- iii. Storage of fresh tomato fruits in “zero energy” cool chamber (S_3) [24°C and 71% RH]

Each treatment consisted of 3 kg sound, unblemished mature green tomato fruits of fairly uniform size were subjected to various forms of packaging and stored in the various storage structures. Determinations were conducted on the various physicochemical parameters on day one and thereafter every three days. Results were analyzed using generalized linear model (GLM) of Statistical Analysis System and means separated using LSD.

Fruit firmness

The firmness of tomato fruits was measured with the aid of HP-FFF analog fruit firmness tester (Qualitest International Inc. Canada) using 0.25cm² test anvil (specifically for tomato fruits). To test the firmness the tester was placed on two different points of the fruit (opposite each other and free of blemishes) with a constant press. The degree of firmness of the fruit was calculated as a quotient of the number directly displayed on the instrument.

Percentage weight loss

The percentage weight loss of the stored tomato fruits was determined as a percentage of the total weight stored.

$$\% \text{ Weight loss in Tomato} = \frac{\text{Initial weight stored} - \text{Final weight}}{\text{Total weight stored}} \times 100$$

Percentage decay

For the determination of % decay, rotted fruits were isolated and the percentage decay calculated as a percentage of the total amount of tomato fruits stored.

$$\% \text{ Decay in Tomato} = \frac{\text{Initial weight stored} - \text{Weight of decayed fruits}}{\text{Total weight stored}} \times 100$$

Ascorbic acid content

The ascorbic acid content of the tomato fruits was determined by the indophenol method as reported by Onwuka (2005). The fruit was pulped using domestic juice extractor (Master Chef Model MC-J2101). Two grams of the blended pulp was weighed and 100 ml of distilled water added to it in a volumetric flask. The solution was filtered using a filter paper to get a clear solution. Fifty milliliters of unconcentrated juice was then pipetted into 100 ml volumetric flask in triplicate. Twenty five milliliters of 20% Metaphosphoric acid was added as a stabilising agent and diluted to 100 ml volume. About 10 ml of the solution was then pipetted into small flask and 2.5 ml of acetone added. The solution was titrated with 2,6 - Dichlorophenol indophenol to a faint pink colour which persisted for roughly 15 seconds. The amount of ascorbic acid in the tomato fruit was calculated as follows:

$$\text{Vitamin C (mg / 100 g)} = 20 \times V \times c$$

Where V= ml indophenol solution in titration and c= mg vitamin C /ml indophenols

Lycopene content

Fresh tomato fruits were squeezed using potable juice extractor (Master Chef Model MC-J2101) to obtain pure tomato juice. The freshly squeezed sample was drawn into a 100µl micro pipette and the outside glass bore was wiped clean using tissue paper. The pipette was allowed to stand to dispel air bubbles from the pipette. The sample was then dispensed into 50 ml separating funnel and closed tightly. Blank samples using 100 µl of water instead of tomato juice was prepared. Eight milliliters of hexane: ethanol: acetone in ratio 2:1:1 was carefully added immediately and kept out of bright light. After about 10 minutes 1 ml of water was also carefully added and vortex again. The sample was allowed to stand for another 10 minutes to allow phases to separate and all air bubbles disappear.

The cuvette of the spectrophotometer was rinsed clean with upper layer from one of the blanks. The liquid was discarded and another fresh blank was used to zero the spectrophotometer (Jenway Model 752) at 503 nm. The absorption of the upper layers of the sample was determined using spectrophotometer at 503 nm. Lycopene content was then calculated

using the following relationship:

$$\text{Lycopene (mg/kg fresh weight)} = (A_{503} \times 137.4) \quad (\text{Onwuka, 2005})$$

RESULTS AND DISCUSSION

Table 1 presents the results of interaction between packaging and storage on tomato fruit firmness for different days in storage. The firmness of fruits on day 3 of the experiment decreased gradually for storage under ambient temperature condition. For storage under refrigeration, fruit firmness increased to 0.0227 kgf before it decreased to 0.0224 kgf as the packaging materials were changed to perforated polyethylene bag and sealed polyethylene bag respectively. On the other hand, the reverse happened in storage in zero energy cool chamber. As the storage methods were changed, fruit firmness decrease before an increase for packaging in kraft paper bag and sealed polyethylene bag respectively. For packaging in perforated polyethylene bag a gradual decrease was observed as the storage methods were changed to refrigeration and zero energy cool chamber. Highest firmness values of 0.0252 kgf were recorded in combination of kraft paper packaging and storage under ambient temperature and it was therefore adjudged the best treatment combination.

On day 6 of the experiment, fruit firmness decreased to 0.0214 kgf and was maintained as the packaging was changed to perforated and sealed polyethylene bags respectively. For storage under refrigeration and storage under zero energy cool chamber the same trend of initial decrease before an increase was followed as the packaging was changed to perforated and sealed polyethylene bags respectively. Fruits firmness decreased for packaging in kraft paper and perforated polyethylene bags respectively as storage was changed from refrigeration to zero cool chamber even though it was maintained for packaging in perforated polyethylene bag. For packaging in sealed polyethylene, firmness decreased initially before it increased as the storage methods were changed to refrigeration and zero energy cool chamber. Highest firmness value of 0.0233 kgf was recorded in combination of kraft paper packaging and ambient temperature storage and this was therefore the best treatment combination.

On day 9 of the experiment, the same trend as in day 6 was observed for storage under ambient temperature condition. For storage under refrigeration, fruit firmness was initially maintained before it increased to 0.0212 kgf as the packaging was changed to perforated and sealed polyethylene bags respectively. Firmness increased initially before it decreased for storage in zero energy cool chamber as the packaging materials were changed to perforated and sealed polyethylene bags respectively. For packaging in perforated polyethylene bag fruit firmness had a gradual increase as the storage methods were changed to refrigeration and zero energy cool chamber. Fruits packaged in sealed polyethylene had an initial increase in firmness before it decreased to 0.0207 kgf. The combination of kraft paper packaging and storage under ambient temperature gave the highest firmness value of 0.0230 kgf and was therefore the best treatment combination.

On day 12 of the experiment, fruit firmness in all the three storage methods followed the same trend of initial decrease before an increase as the packaging materials were changed to perforated polyethylene and sealed polyethylene bags respectively.

Table 1. Interaction between packaging and storage environment on tomato fruit firmness (kgf)

| Storage | 3Days | | | 6Days | | | 9Days | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 0.0252 | 0.0243 | 0.0234 | 0.0233 | 0.0214 | 0.0214 | 0.023 | 0.0208 | 0.0208 |
| S ₂ | 0.0222 | 0.0227 | 0.0224 | 0.0204 | 0.0199 | 0.0208 | 0.0209 | 0.0209 | 0.0212 |
| S ₃ | 0.0224 | 0.0222 | 0.0227 | 0.0201 | 0.0199 | 0.021 | 0.0208 | 0.0211 | 0.0207 |
| Mean | 0.0231 | | | 0.0209 | | | 0.0211 | | |
| P≤F | 0.0067 | | | 0.0001 | | | 0.0001 | | |
| LSD | 0.0010 | | | 0.0007 | | | 0.0006 | | |
| Storage | 12Days | | | 15Days | | | 18Days | | |
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 0.0248 | 0.0225 | 0.0232 | 0.0248 | 0.0207 | 0.0204 | 0.0233 | 0.021 | 0.0214 |
| S ₂ | 0.022 | 0.0217 | 0.0224 | 0.0206 | 0.0212 | 0.0204 | 0.021 | 0.0216 | 0.0211 |
| S ₃ | 0.0213 | 0.0211 | 0.0221 | 0.0213 | 0.0216 | 0.021 | 0.022 | 0.0227 | - |
| Mean | 0.0223 | | | 0.0214 | | | 0.0217 | | |
| P≤F | 0.0006 | | | 0.0001 | | | 0.005 | | |
| LSD | 0.0007 | | | 0.0050 | | | 0.0059 | | |

P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bags; S₁: Storage of fruits at ambient room temperature (32 °C and 29% RH); S₂: Storage of fruits at refrigerated chamber (11 °C and 90-95% RH); S₃: Storage of fruits in "zero energy" cool chamber (24 °C and 71% RH)

Fruit firmness had a general decrease in all the three packaging materials as the storage methods were changed. The best combination here also was kraft paper packaging and storage under ambient temperature condition as it recorded highest firmness value

On day 15 of the experiment, fruit firmness gradually decreased to 0.0207 and subsequently to 0.0204 kgf as the packaging materials were changed to perforated and sealed polyethylene bags respectively. Fruits stored under refrigeration and in zero energy cool chamber, followed the same trend of initial increase and subsequent decrease as the packaging were changed to perforated and sealed polyethylene bags respectively. Firmness of fruits decreased before it increased for packaging in kraft paper bag. For fruits packaged in perforated polyethylene a gradual increase was observed as storage methods was changed to refrigeration and zero energy cool chamber. Firmness was initially maintained as storage method was changed to refrigeration before an increase when changed to zero energy cool chamber. Combination of kraft paper packaging and storage under ambient temperature gave the highest firmness and was therefore the best combination.

On day 18 of the experiment, firmness value fruits stored under ambient temperature decreased before it increased as the packaging materials were changed; while the reverse was recorded in fruits stored under refrigeration. For storage in zero energy cool chamber an increase in fruit firmness was recorded as the packaging was changed to perforated polyethylene bag. Fruit firmness for fruits packaged in kraft paper and in perforated polyethylene bag followed the same trend as in day 15 of the experiment while in fruits packaged in sealed polyethylene, firmness decreased to 0.0211 kgf. Here also combination of kraft paper packaging and storage under ambient temperature gave the highest firmness and was therefore the best combination. Combination of sealed polyethylene bag and zero energy cool chamber rotted away and therefore was the worst treatment combination.

Fruit firmness values ranged from 0.0199 kg to 0.0252 kgf. The values in this study were lower than reported values (Ranatunga et al., 2014). The trend for firmness values was not regular as it decreases initially, increased and later decreased. The results of this study are contrary to the report of Singh and Yadav (2015) who reported only a decrease in firmness as storage progressed. Packaging in kraft paper bag and storing in room at ambient temperature recorded the highest firmness value of 0.0252 kgf and 0.0248 kgf on 3rd and 12th days of storage respectively. This could be attributed to the type of packaging and also storage environment. Kraft paper creates a kind of modified atmosphere package which regulates the exchange by gases with the outer environment and also prevents condensation of moisture which exposes the fruits to attack. This fact has been corroborated by Sammi and Masud (2009) that packaging significantly reduces fruit weight loss which in turn maintains cell turgor and firmness in the affected fruit.

Table 2 presents the results of interactions between packaging and storage environment on percentage weight loss of tomato fruits. The percentage weight loss on day 3 of the experiment for fruits stored under ambient conditions decreased to 0.819% before it increased to 1.451%. For fruits stored in the refrigerator and those in zero energy cool chamber, the percentage weight loss decreased as the packaging materials were changed to perforated polyethylene and sealed polyethylene bags. As the storage methods were changed the percentage weight loss in fruits packaged in kraft paper bag and sealed polyethylene had a decreased trend, while for fruits packaged in perforated polyethylene bag initially increased to 1.313% before it decreased to 0.255%.

Table 2. Interaction between packaging and storage environment on tomato fruit weight loss (%)

| Storage | 3Days | | | 9Days | | | 12Days | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 5.418 | 0.819 | 1.451 | 4.313 | 19.577 | 4.691 | 3.708 | 5.347 | 9.527 |
| S ₂ | 1.441 | 1.323 | 0.859 | 1.514 | 0.164 | 0.229 | 1.021 | 0.169 | 0.163 |
| S ₃ | 0.912 | 0.255 | 0.237 | 4.718 | 6.826 | 2.609 | 1.44 | 9.466 | 3.203 |
| Mean | 1.413 | | | 4.959 | | | 3.722 | | |
| P≤F | 0.0001 | | | 0.0004 | | | 0.0001 | | |
| LSD | 0.871 | | | 5.634 | | | 2.768 | | |
| | 15Days | | | 18Days | | | | | |
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | | | |
| S ₂ | 11.786 | 5.325 | 4.636 | 1.927 | 0.369 | 0.448 | | | |
| S ₃ | 3.533 | 0.223 | 5.432 | 0.5 | 5.32 | - | | | |
| Mean | 3.783 | 12.751 | 2.65 | 3.859 | | | | | |
| P≤F | 6.118 | | | 0.0002 | | | | | |
| LSD | 0.0267 | | | 1.499 | | | | | |
| | 4.712 | | | | | | | | |

P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bags; S₁: Storage of fruits at ambient room temperature (32 °C and 29% RH); S₂: Storage of fruits at refrigerated chamber (11 °C and 90-95% RH); S₃: Storage of fruits in "zero energy" cool chamber (24 °C and 71% RH)

A combination of zero energy cool chamber storage and sealed polyethylene package gave the least percentage weight loss of 0.237% and was therefore the best treatment combination. On day 9 of the experiment, the percentage weight loss of tomato fruits stored under ambient temperature conditions and those stored in zero energy cool chamber had an opposite trend of day 3. For fruits stored under refrigeration, the percentage weight loss decreased before it slightly increased. The percentage fruit weight loss decreased initially before it increased in all the packaging materials as the storage methods

were changed to refrigeration and zero energy cool chamber respectively. Combination of packaging in perforated polyethylene bag and storage under refrigeration and was the best for recording the least percentage weight loss of 0.164%.

The percentage weight loss on day 12 of the experiment for fruits stored under ambient temperature conditions increased as the packaging was changed to perforated and sealed polyethylene bags respectively; while the opposite was recorded in fruits stored under refrigeration. In fruits stored in zero energy cool chamber, the percentage weight loss increased to 9.466% before decreasing to 3.203% as the packaging was changed to perforated and sealed polyethylene bags respectively. The same trend as in day 9 was observed as the storage methods were changed. Packaging in sealed polyethylene and storage under refrigeration had the least percentage weight loss of 0.163% and was therefore the best combination.

On day 15 of the experiment the percentage weight loss in fruits for fruits stored under ambient conditions decreased as the packaging materials were changed to perforated and sealed polyethylene bags respectively. For fruits stored under refrigeration, the percentage weight loss decreased before it increased and the opposite occurred in fruits stored in zero energy cool chamber as the packaging materials were changed to perforated and sealed polyethylene bags respectively. Fruits packaged in kraft paper bag and those packaged in perforated polyethylene bag followed same trend as in day 9 and 12 of the experiment. On the other hand, a reverse trend was observed in fruits packaged in sealed polyethylene bag. A combination of packaging in perforated polyethylene bag and storage under refrigeration had the least percentage weight loss of 0.223% and was therefore the best treatment combination.

The percentage weight loss of fruits on day 18 of the experiment for fruits stored under ambient conditions had an initial increase before a decrease while the opposite was recorded for fruits stored under refrigeration as the packaging materials were changed to perforated and sealed polyethylene bags respectively. Fruits stored in zero energy cool chamber recorded an increase to 5.320% as the packaging was changed to perforated polyethylene bag. The percentage weight loss in fruits packaged in kraft paper bag decreased as the storage method was changed to refrigeration and zero energy cool chamber while opposite trend was recorded in fruits packaged in sealed polyethylene bags. Fruits packaged in perforated polyethylene had an initial and sharp decrease before an increase to 5.320%. The best treatment combination involved packaging in perforated polyethylene bag and storage in refrigerator while packaging in sealed polyethylene bag and storing in zero energy cool chamber was the worst treatment combination having rotted away.

Interaction between packaging and storage on weight loss of the tomato fruits were significant ($P \leq 0.01$) on 3, 9, 12, 15 and 18 days of storage. The weight loss ranged from 0.163 – 19.577 %. Treatment combination involving packaging in mildly perforated PE bag and stored at ambient temperature had the highest weight loss. This phenomenon could be attributed to the higher storage temperature (ambient) which could be aggravated by the polyethylene sheet. The results agreed with the report of Nasrin (2008). The physiological weight loss of tomato fruits increased with advancement of storage period. The weight loss was highest in non treated but packed fruits. The loss in weight could be attributed to respiration and transpiration which result in moisture loss (Nasrin, 2008).

The results of interaction between packaging and storage environment on percentage fruit rot on different days in storage are presented on Table 3. On day 3 of the experiment, the percentage rot decreased initially before increasing in fruits stored under ambient condition and also in those stored under zero energy cool chamber as the packaging were changed to perforated and sealed polyethylene bags respectively. Fruits stored in the refrigerated chamber recorded gradual and slight increase in percentage rot as the packaging was changed. As the storage methods were changed, the percentage rot

decreased before it increased in all the packaging materials. Fruits packaged in kraft paper bag and stored in refrigerator were the best treatment combination having recorded no rot.

On day 6 of the experiment, fruits stored under ambient conditions those stored under refrigerator had an increase in percentage rot before a decrease even though it was very low in fruits stored under refrigeration. A reverse trend was observed in fruits stored in zero energy cool chamber. The percentage fruit rot on days followed the same trend as in day 3 of the experiment as the storage methods were changed. The best treatment combination on day 6 was same as in day 3.

The percentage fruit rot on day 9 of the experiment for fruits stored under ambient conditions recorded an increase as the packaging was changed to perforated and sealed polyethylene bags respectively. For fruits stored under refrigeration and in zero energy cool chamber there was an initial decrease before an increase as the packaging materials were changed. Fruits packaged in perforated polyethylene and stored under refrigeration recorded no rot and were therefore the best combination.

On day 12 of the experiment, the percentage fruit rot for fruits stored under ambient conditions and also fruits stored under refrigeration followed the same trend as in day 9. On the other hand fruits stored in zero energy cool chamber recorded increase in percentage rot as the packaging materials were changed. The best combination was same as in day 9 of the experiment.

On day 18 of the experiment, the percentage fruit rot in all the storage methods recorded an increase as the packaging materials were changed. The percentage fruit rot recorded a decrease in fruits packaged in kraft paper and also in those packaged in sealed polyethylene bag the storage methods were changed. In fruits packaged in perforated polyethylene percentage rot decrease initially to 0.613% before increasing to 17.540%. The best combination was packaging in kraft paper bag and storage in zero energy cool chamber because it recorded no rot while fruits packaged in sealed polyethylene and stored in zero energy cool chamber rotted away and was therefore the worst combination.

On day 21 of the experiment, the percentage fruit rot decreased initially to 0 before increasing to 7.275% for fruits packaged in kraft paper bag. On the other hand, fruits packaged in perforated polyethylene bag recorded a sharp decrease to 1.927% as the storage method was changed to refrigeration. The percentage rot in fruits stored under ambient conditions decreased while in fruits stored under refrigeration it increased before having slight decrease. The best combination was packaging in kraft paper bag and storage under refrigeration. Treatment combinations that rotted away were the worst combinations.

The interactions for the effect of packaging and storage conditions on tomato rot were also significant ($P \leq 0.01$) on 3,6,9,12,18 and 21 days of storage. The percentage rot recorded were from 0 – 72.181 %. The values were within the range of Moneruzzaman et al. (2009). The highest percentage of 72.181 % and 58.196 % were obtained by treatments involving fruits packaged in sealed polyethylene bag and stored in room at ambient temperature respectively. The two treatments with high rate of rotting all involved polyethylene bag as the mean of packaging and as a result of moisture condensation which could support growth of some micro-organisms and also encourage cross contamination of healthy fruits.

The results of the interaction between packaging and storage on ascorbic acid of fruits during storage are presented on Table 4. On day 9 of the experiment the ascorbic acid content in fruits stored under ambient conditions recorded an increase while those stored under refrigeration recorded a decrease as the packaging materials were changed. Fruits stored under zero energy cool chamber initially had an increase before a decreased. As the storage methods were changed, the ascorbic acid increased initially before it decreased. Fruits packaged in sealed polyethylene bag recorded the opposite. On the

other hand fruits packaged in perforated polyethylene bag recorded increase in ascorbic acid as the storage methods were changed. The best combination was packaging in kraft paper and storage under refrigeration. Packaging in kraft paper bag and storage under refrigeration recorded highest amount of 24.421 mg/100g and was therefore the best combination.

Table 3. Interaction between packaging and storage environment on tomato fruit rot (%)

| Storage | 3 Days | | | 6 Days | | | 9 Days | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 4.487 | 3.358 | 9.456 | 7.034 | 13.371 | 9.079 | 8.751 | 19.161 | 20.844 |
| S ₂ | 0 | 0.044 | 0.063 | 0 | 0.147 | 0.06 | 0.062 | 0 | 0.056 |
| S ₃ | 9.612 | 4.464 | 9.533 | 19.36 | 8.582 | 17.337 | 32.092 | 29.461 | 46.212 |
| Mean | 4.558 | | | 8.33 | | | 17.293 | | |
| P≤F | 0.0001 | | | 0.0006 | | | 0.0125 | | |
| LSD | 2.250 | | | 3.110 | | | 9.040 | | |
| | 12 Days | | | 18 Days | | | 21 Days | | |
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 5.276 | 20.027 | 25.144 | 6.868 | 16.73 | 58.196 | 15.037 | 10.19 | - |
| S ₂ | 0.008 | 0 | 0.622 | 0.056 | 0.613 | 3.101 | 0 | 1.927 | 1.193 |
| S ₃ | 38.316 | 47.617 | 72.181 | 0 | 17.54 | - | 7.275 | - | - |
| Mean | 23.367 | | | 10.391 | | | 4.428 | | |
| P≤F | 0.0006 | | | 0.0001 | | | 0.013 | | |
| LSD | 10.340 | | | | | | 2.087 | | |

P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bags; S₁: Storage of fruits at ambient room temperature (32 °C and 29% RH); S₂: Storage of fruits at refrigerated chamber (11 °C and 90-95% RH); S₃: Storage of fruits in "zero energy" cool chamber (24 °C and 71% RH)

On day 18 of the experiment, the amount of ascorbic acid in fruits stored under ambient conditions decreased initially before it increased. The opposite was observed in fruits stored under refrigeration. On day 18 of the experiment, fruits packaged in kraft paper bag recorded an increase in ascorbic acid while those packaged in sealed polyethylene bag recorded a decrease in ascorbic acid as the storage methods were changed. In fruits packaged in perforated polyethylene bag the amount of ascorbic acid increased initially to 25.506 mg/100g before it decreased to 18.050 mg/100g. Highest amount of ascorbic acid was observed in fruits packaged in kraft bags and stored under zero energy cool chamber and this was therefore the best combination. Fruits packaged in sealed polyethylene and stored in zero energy cool chamber decayed and was therefore the worst combination. Packaging in kraft paper bag and storage under zero energy cool chamber had the highest ascorbic acid and was therefore the best combination. The worst combination was packaging in sealed polyethylene and storage in zero energy cool chamber because it rotted away.

The interaction between packaging and storage conditions on Ascorbic acid content was also significant on only 9 and 18 days of storage. The Ascorbic acid values ranged from 14.804 – 28.500 mg/100g. Similar range of values was reported by Gharezi et al. (2012) in their work on effect of postharvest treatment on stored cherry tomatoes. The highest Ascorbic acid value of 28.500 mg/100g was recorded by fruits packaged in kraft paper bag and stored in zero energy cool chamber. This could be as a result of storage method because Singh and Yadav (2015) reported LDPE packaging combined with ECC to be better in maintaining tomato quality. Shahnawuz et al. (2012) also stated that PE was a better packaging than paper in terms

of retaining quality of tomato fruits. Ascorbic acid values increased with time. Sammi and Masud (2007) observed that an increase in ascorbic acid is an indication that the fruit is still in ripening stage while a decrease indicates senescent fruit.

Results of interaction between packaging and storage on lycopene content during storage are presented on Table 5. The amount of lycopene on day 12 of the experiment in fruits stored under ambient temperature initially decreased before it later increased slightly as the packaging materials were changed. The opposite was observed in fruits stored under refrigeration while fruits stored in zero energy cool chamber recorded a fair decrease in lycopene content. As the storage methods were changed, the lycopene content in fruits packaged in kraft paper and perforated polyethylene bags initially decreased before it later increased. Fruits packaged in perforated polyethylene recorded an increase in lycopene as the storage methods were changed. Packaging in perforated polyethylene and storage in ambient conditions recorded least lycopene of 28.923 mg/kg and as such was the best combination.

Table 4. Interaction between packaging and storage environment on tomato ascorbic acid content (mg/100g)

| Storage | 9 Days | | | 18 Days | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 15.897 | 17.462 | 20.449 | 20.356 | 17.867 | 20.45 |
| S ₂ | 24.421 | 23.084 | 14.804 | 21.636 | 25.506 | 18.758 |
| S ₃ | 16.204 | 24.001 | 17.834 | 28.5 | 18.05 | - |
| Mean | 19.425 | | | 21.31 | | |
| P≤F | 0.011 | | | 0.052 | | |
| LSD | 7.588 | | | 6.656 | | |

P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bags; S₁: Storage of fruits at ambient room temperature (32 °C and 29% RH); S₂: Storage of fruits at refrigerated chamber (11 °C and 90-95% RH); S₃: Storage of fruits in "zero energy" cool chamber (24 °C and 71% RH)

Table 5. Interaction between packaging and storage environment on tomato lycopene content (mg/kg)

| Storage | 12 Days | | | 15 Days | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | P ₁ | P ₂ | P ₃ | P ₁ | P ₂ | P ₃ |
| S ₁ | 100.867 | 28.923 | 39.911 | 106.787 | 42.413 | 44.689 |
| S ₂ | 29.186 | 42.191 | 36.146 | 43.209 | 35.458 | 34.861 |
| S ₃ | 96.581 | 63.127 | 46.199 | 139.765 | 64.603 | 36.49 |
| Mean | 54.294 | | | 58.844 | | |
| P≤F | 0.0005 | | | 0.0001 | | |
| LSD | 24.330 | | | 31.610 | | |

P₁: Packaging fruits in Kraft paper bags; P₂: Packaging fruits in mildly perforated low density PE bags with 6 holes; P₃: Packaging fruits in sealed low density low density PE bags; S₁: Storage of fruits at ambient room temperature (32 °C and 29% RH); S₂: Storage of fruits at refrigerated chamber (11 °C and 90-95% RH); S₃: Storage of fruits in "zero energy" cool chamber (24 °C and 71% RH)

On day 15 of the experiment, the lycopene content in fruits stored under ambient conditions decreased initially before a slight increase as the packaging materials were changed. Fruits stored under refrigeration and also under zero energy cool chamber recorded a decrease in lycopene as the packaging materials were changed. The lycopene content in all packaging materials decreased initially before it later increased. The best combination was packaging in sealed polyethylene bag and storage in refrigerator because it recorded the least lycopene of 34.861 mg/kg.

Values for lycopene ranged from 29.186 – 139.765 mg/kg. The values were similar to reported ones reported by Luna – Guevera et al. (2014) and Brandt et al. (2013). Tomatoes packaged in Kraft paper bag and stored in zero energy cool chamber and those packaged in kraft paper bag and stored in room at ambient temperature recorded highest values of 139.765 mg/kg and 106.787 mg/kg respectively. This is just the opposite of report of Abiso et al. (2015) that maximum amount of lycopene was recorded in fruits stored in room at ambient temperature followed by fruits stored in zero energy cool chamber. Increase in lycopene as ripening progressed was due to degradation of Chlorophyll and synthesis of colour pigments particularly lycopene (Hobson and Davis, 1971).

CONCLUSION

Based on the results presented it can be concluded that packaging in kraft paper bag and zero energy cool chamber was the best treatment combinations because it maintained physico-chemical parameters of the tomato fruits within an acceptable limit up to 21 days of storage. The treatment combination could maintain tomato fruit quality without the problem of chilling injury which aggravates weight loss and rotting of fruits. This combination could therefore be recommended for short term storage of fresh tomato fruits.

REFERENCES

- Abiso, E., Satheesh, N. and Hailu, A. 2015. Effect of Storage Methods and Ripening Stages on Postharvest Quality of Tomato (*Lycopersicon esculentum*) CV. Chali. *Annals. Food Science and Technology*, 6 (1): 127-137.
- Adedeji, O, Taiwo, K., Akanbi, C. and Ajani, R. 2006. Physico-chemical properties of four Tomato cultivators grown in Nigeria. *Journal of Food Processing and Preservation*, 30 (1); 79-86.
- Ayandiji, A. O. R., Adeniyi, O. D. 2011. Determination of postharvest losses among Tomato Farmers in Imeko-Afon Local Government Area of Ogun State, Nigeria. *Global Journal of Science Frontier Research*, 11(5): 22-28.
- Basu, A. and Imrhan, V. 2007. Tomatoes Versus Lycopene in Oxidative Stress and Carcinogenesis: Conclusions from Clinical Trials. *European Journal of Clinical Nutrition*, 61 (3): 295-303.
- Brandt, S., Lugasi, A., Barna, E., Hovari, J., Pek, Z. and Helyes, L. 2003. Effects of growing Methods and Conditions on the Lycopene Content of Tomato Fruits. *Acta Alimentaria*, 31 (3): 269-278.
- De-Lennoy, G. 2001. Tomato. In Reamaekers, R. H. (Ed). *Crop Production in Tropical Africa*. Directorate general for International Co-operation. Brussels, Belgium, Pp. 467-475.
- FAOSTAT 2014. *Global Tomato Production in 2012*. FAO, Rome.
- Gharezi, M., Joshi, N. and Sadeghlan, E. 2012. Effect of Post-harvest Treatment on Stored Cherry Tomatoes. *Journal of Nutrition and Food Science*, 2 (8): 1-10.
- Hobson, G. and Davies, J. 1971. The Tomato. In *The Biochemistry of Fruits and their Products*. A.C Hulme Academic press, N.Y Pp. 437-482.
- Kutama A. S., Aliyu, B. S. and Mohammed, I. 2007. Fungal Pathogens Associated with Tomato Wicker Storage Baskets. *Science World Journal*, 2 (2): 38-39.
- Luna-Guevera, M. L., Gonzaliez, O. J., Luna-Guevera, J. J., Harnandez-Carranza, P. and Ochoa-Valesco, C. E. 2014. Quality parameters and Bioactive Compounds of Red Tomatoes (*Solanum lycopersicum* L.) CV Roma VF at Different Postharvest Conditions. *Journal of Food Res.* 3 (5): 8-18.

- Moneruzzaman, K. M., Hossein, A. B. M. S., Sani, W., Saifuddin, M. and Alenazi, M. 2009. Effect of Harvesting and Storage Conditions on the Postharvest Quality of Tomato (*Lycopersicon esculentum* Mill) CV Roma VF. Australian Journal of Crop Science, 3 (2): 113-121.
- Nasrin, T. A. A., Molla, M. M., Hossein, M. A., Alam, M. S. and Yasmin, L. 2008. Effect of Postharvest Treatments on Shelf life and Quality of Tomato. Bangladesh J. Agric. Res. 33 (3): 579-585.
- Onwuka, G. F. 2006. Food Analysis and Instrumentation: Theory and Practice. Naphthali Prints Lagos, Nigeria. Pp. 1-45.
- Ranatunga, C. L., Jayuweera, H. H. E., Suraweera, S. K. K. and Ariyaratne, T. R. 2009. Effects of measurement of non-destructive firmness on Tomato Quality and Comparison with Destructive methods. Proceedings of the Technical sessions, 25 (2005): 29-35.
- Sammi, S. and Masud, T. 2007. Effect of Different Packaging Systems on the Storage life and Quality of Tomato (*Lycopersicon esulectum* Mill.) Var Rio Grande during different ripening stages. Internet Journal of Food Safety, 9:37-44.
- Sammi, S. and Masud, T. 2009. Effect of Different Packaging Systems on the Storage life and Quality of Tomato (*Lycopersicon esulectum* Mill.) Var Rio Grande during storage. International Journal of Food Science and Technology, 44(5):918-926.
- Shahnawaz, M., Sheikh, S. A., Soomro, A. H., Panhwar, A. A and Khaskheli, S. G. 2012. Quality Characteristics of Tomatoes (*Lycopersicon esculentum*) stored in various wrapping materials. African Journal of Food Science and Technology, 3 (5): 123-128.
- Sibomana, C. I., Opiyo, A. M. and Aguyoh, J. N. 2015. Influence of soil moisture levels and Packaging on Post-harvest Qualities of Tomatoes (*Solanum lycopersicum*). African Journal of Agricultural Research, 10 (2): 1392-1400.
- Singh, Y. and Yadev, Y. K. 2015. Effect of Different Storage Environment on Quality Characteristics of Tomato and Kinnow Fruits. Agric. Engr. Int.: CIGR Journal, 17 (1): 238-245
- Srivdya, S., Raddy, P. S. S., Umajyothi, K., Sudhavani, V. and Reddy, R. 2014. Effect of Different LDPE Packaging materials on Shelf life and Nutrition Quality of Tomato CV. Lakhshmi under Ambient Conditions. Plant Archives, 14 (2): 1123-1126.