

Effect of maturity stage on quality and shelf life of tomato (*Lycopersicon esculentum* mill) using refrigerator storage system

Famuyini Monday John^{1*}, Olalusi Ayoola Patrick², Sedara Adewale Moses³

¹The Federal University of Technology, Faculty of Engineering and Engineering Technology, Department of Agricultural and Environmental Engineering, Akure, Nigeria

²The Federal University of Technology, Faculty of Engineering and Engineering Technology, Department of Agricultural and Environmental Engineering, Akure, Nigeria

³The Federal University of Technology, Faculty of Engineering and Engineering Technology, Department of Agricultural and Environmental Engineering, Akure, Nigeria

*Corresponding Author: mjfamuyini.fj@gmail.com

Famuyini Monday John ORCID: <https://orcid.org/0000-0003-2080-0446>

Abstract

Tomatoes (*Lycopersicon Esculentum* Mill) are well known vegetable that contains vitamins, antioxidants and other health beneficial substances. This study evaluates quality (vitamin C, protein, fat, crude fibre, ash content, moisture content, carbohydrate, weight loss, firmness and antioxidant activity) and shelf- life of tomatoes under refrigerator storage method at 10°C using three maturity stages (breaking stage, pale red stage and light red stage) of 'Beefmaster HYBRID VFNASt' tomato varieties cultivated in a greenhouse, harvested and stored for 18 days. The physical qualities were determined during storage whilst antioxidant activity (lycopene and carotenoid concentrations) was evaluated before and after 18 days of storage. The results obtained shows that before storage; tomatoes has high moisture content (95.36%) and protein content (1.04%) at breaking stage, highest value of fat content (0.59%) and crude fibre content (1.13%) was recorded at pale red stage, while the highest ash content (0.43%), carbohydrate (3.17%), carotenoid content (0.3272 mg/g), lycopene content (0.7309 mg/g) and vitamin C content (0.1268 mg/g) was recorded at light red stage. An increase was observed in the antioxidant activities and proximate composition after 18 days of storage. The concentration of vitamin C content of tomato fruit after storage compare with the fresh sample is significantly ($p < 0.05$) depends on maturity stages of the tomato fruit. The highest nutritional value (quality and shelf-life) was recorded for breaking stage. The results obtained also shows that carotenoid and vitamin C contents of the tomato fruits slight increase at the end of the storage period in breaking stage and this increase is significantly depends on maturity stage. It was observed that ripening stage has significant influence on the nutritional values which indicate that the ideal maturity stage to maintain optimal shelf life and nutritional quality is breaking stage of tomato fruit which is the most suitable for storage.

Keywords: Tomatoes, Maturity stages, Refrigerator system, Shelf life, Quality

Research article

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular and widely grown vegetables in the world; it belongs to the botanical family *Solanaceae*, it (Chapagain and Wiesman, 2004) is a rich source of minerals and vitamins (A, B, and C). It is second most important in the world next to potato both in terms of area and volume of production. The main producers and exporters in the world are China, USA, Turkey, Egypt and India (USDA, 2007). Since the consumers purchase the fruits on the basis of quality, the quality of tomato fruit is largely dependent on the stage of maturity of fruits and various ripening conditions.

Tomato plants have many branches which spread from 24-72 inches and recumbent when fruiting but a few forms are compact and up right leaves are more or less hairy, strong odorous, pinnate compound, up to 18 inches long (Harvey and Chan, 1983). The flowers are yellow in 2cm across pendant and clustered. Fruits vary in diameter from half to three inches or more, there are usually red, scarlet or yellow that vary in shape from almost spherical through over and elongated to pear shaped. Tomato varieties were classified into two groups: determinate and indeterminate (Henry, 2018). Determinate are tomato varieties that are space-saving or bush type in the garden. They are grown with or without support. The tomatoes ripen within a concentrated time period. This type of varieties is considered if you want a supply of ample amounts of tomatoes for canning while indeterminate are tomato varieties that should be staked, trellised, or caged for best results. Mini tomato is another variety of tomatoes that stands out as a product with high aggregated value and its market price is 20 to 30% higher than traditional tomatoes (Junqueira et al., 2011). This type of tomato has high level of carotene and antioxidant activity than conventional tomatoes (Raffo et al., 2002). These properties are intensified when the fruits are at the most advanced ripeness stage, ideal for consumption (Kader, 2008).

In Nigeria, the crop is regarded as the most important vegetable in terms of production, marketing and consumption Its production zones cover the Northern and Upper Regions as well as the Southern Region of Nigeria (Nkansah et al., 2003). Tomato maturity stage is classified into six stages (Green, Breaking, Turning, Pink or Pale red, Light Red, and Red) based on its colour (USDA, 2007). The harvesting time of tomato is an important issue to be considered in order to determine its quality and post-harvest behaviour. Tomato must be harvested at the right time because overripe tomato is more susceptible to physical injury than ripe and pink ones, as a result of this, colour is the most important criterion to determine the harvesting time of tomato. The fruit is soft, succulent, berry red or yellow in color contain too many cells of small seeds surrounded by jelly like pulp. It also consists of water and soluble and insoluble solids. Soluble solids are traditionally expressed as degrees Brix ($^{\circ}$ Brix) and mainly consist of sugars (sucrose and fructose) and salts (Beckles, 2011); therefore, tomato solids are very valuable at the factory processing. Higher amount of tomato solids need less amount of fruits to produce the same amount of tomato products (Beckles, 2011; Siddiqui, 2015). It is used raw in salads served as a cooked vegetables used as an ingredient of various prepared dishes and pickles (Wills et al., 2004).

Quality of agricultural product is an important factor to both the producers and consumers (Idah and Aderibibge, 2005). Usually after harvesting, the quality of fruits and vegetables cannot be improved. All efforts are directed towards production quality. The following are some of the qualities that aid extension of shelf life during or after storage of some of agricultural produce such as tomato. viz: firmness, mass loss, pH level, colour measurement, vitamin C content etc. The proximate chemical composition of some agricultural fruit such as sweet peppers, tomato and eggplant are presented in Table 1 (USDA, 2007). The data gives an overall indication of the relative nutritive value of each species at the time of commercial utilization.

Post-harvest losses in tomato cannot be eliminated, but can be reduced within certain limits by maintaining appropriate maturity stage of harvesting. Post-harvest losses in quality of tomato fruit are related to immaturity at harvest, inadequate initial quality control, incidence and severity of physical damage, exposure to improper temperature, and delays between harvest and consumption (Melkamu et al., 2008).

Extending the quality and shelf life of tomato is very important for domestic and export marketing. Therefore, extension of the quality and shelf life of tomato fruit by harvesting at appropriate maturity stage accompanied with proper post-harvest handling can be achieved to some level. Hence, Olympio and Kukuaih (2002) suggested that, there should be need to come up with varieties that could withstand the transportation damages or improve the handling ability of varieties grown.

In this study, the effect of maturity stage on quality and shelf life of tomato fruit are investigated with the view to generate basic data or information that can be used to determine the best maturity stage that will minimize post-harvest handling losses and maintain optimal shelf life and quality value of the tomato fruit.

Table 1. Approximated composition of fresh eggplant, pepper and tomato fruit at the stage of commercial consumption.

Constituent	Amount 100 g-1 fresh weight		
	Eggplant	Pepper (red)	Tomatoes (red)
Water	92.40%	92.20%	94.50%
Carbohydrates	5.70%	6.00%	3.90%
Protein	1.00%	1.00%	0.90%
Fat	0.20%	0.30%	0.20%
Fibre	3.40%	2.10%	1.20%
Sugar (total)	2.35%	4.20%	2.60%
Calcium	9 mg	7 mg	10 mg
Magenesium	14 mg	12 mg	11 mg
Phosphorus	25 mg	26 mg	24 mg
Iron	0.24 mg	0.43 mg	0.27 mg
Potassium	230 mg	210 mg	237 mg
Vitamin A	27 IU	3100 IU	830 IU
Thiamine	0.04 mg	0.054 mg	0.04 mg
Riboflavin	0.037 mg	0.085 mg	0.02 mg
Niacin	0.65 mg	0.98 mg	0.6 mg
Vitamin C	2.2 mg	127.7 mg	12.7 mg
Energy	24 kcal	31 kcal	18 kcal

Source; (USDA 2007)

MATERIALS and METHODS

Experimental Procedure

The tomato fruits (*lycopersicon esculentum* mill) used for the study is ‘Beefmaster Hybrid VFNASt’ cultivated in greenhouse at Tisco farm limited, Emure-ile Owo in Ondo State Nigeria to ensure adequacy and avoid bias. It belongs to an indeterminate group of tomato varieties. It takes 80 days before it reaches maturity stage.

Temperature, humidity, ventilation and irrigation of the greenhouse was measured by a fully automated (Hortimax and Netherlands) measurement system before and during the experiment. Cultural practices such as spraying of insecticides (Karate at 30 ml/15L Knapsack) and fungicides (10 g of Shavit F 71.5 WP) and staking was carried out when necessary.

Organic compound fertilizer called bonus (foliar fertilizer in liquid form) was applied at the rate of 7-8g into 15 litres of water at nursery and 1g into 2litres of water to each plant, in three (3) weeks after transplanting in September 2018. Three weeks after the bonus application, multi K of potassium sulphate was also applied. Thirty of the tagged fruits inside the greenhouse was harvested on the same day when they reached the expected maturity ripe stage. Ripe stages of fruit were determined on the field using subjective evaluations of fruit size, position on the plant, smoothness of fruit shoulder and by observation of locular development in some representative fruit (Toivonen, 2007).

Fruit was harvested at three (3) different ripening stages (Breaking ripening stage, Pale red ripening stage and Light red ripening stage) in 17th December, 2019. After harvest, fruits were held overnight at about 10-15^oC and transported the following day to the post graduate Laboratory of Biochemistry Department of Federal University of Technology Akure, Ondo State of Nigeria. Upon arrival at the laboratory, the tomato fruit was sorted and stored in Haier thermocool fridge of model number HRF.260Sliver with current rating 150 W/1.6A and freezing capacity of 3.5 kg/24h for a period of eighteen (18) days. Fruit quality and shelf-life was evaluated before, during and after storage from 18th December to 31st December 2019.

Experiment Evaluation

Weight loss, and firmness was examined at every three (3) days interval of storage while vitamin C, carotenoid, lycopene and proximate compositions was examined before and after the experiment.

Weight loss

The tomato fruits were weighed before and during the storage period using adventurer pro Av8101 balance

$$\text{Weight loss (\%)} = \frac{A - B}{A} \times 100\% \quad (1)$$

Where, A is initial weight of the sample with the weight of basket and B is final weight of the sample with the weight of basket in gram.

Fruit firmness

Firmness of the tomato fruit was determined using fruit penetrometer GY-3 at an interval of three days for the period of 18 days at which the fruit has lost its firmness. The value was determined as follows:

$$\text{Firmness (\%)} = \frac{\text{Reading}}{\text{no_of_replicate}} \times \frac{23.8}{1} \quad (2)$$

Where, reading is the addition of values obtained from the measurement for example a+b+c, no of replicate is the number of time the reading was taken for each sample examined and 23.8 is constant (AOAC, 2005).

Vitamin C

It was determined following methodology described by (Vinha et al., 2012; AOAC, 2005). Five gram of each sample was treated with 90 ml of oxalic acid (0.4%) for 1 hour and homogenized.

The 2 ml of filtered extracts was diluted in 50 ml of distilled water and titrated with Tillman's reagent. Quantification was obtained from a standard curve based on the reduction of DIP and results was expressed as mg of ascorbic acid/100 g.

Lycopene

It was determined following methodology described by (Fish et al., 2002). One hundred gram of the sample was ground to a homogeneous puree using an electric tissue blender and transferred into 250 cm³ beaker. Subsequently, 50 cm³ hexane-acetone-ethanol mixture (2:1:1 v/v/v) was added into the beaker and shaken for 15 min on an electric shaker. Thereafter, 3 cm³ of distilled water was added and the sample was shaken for another 5 min. The solution was transferred into 250 cm³ separator funnel and allowed to stand for 5 min to enable phase separation thereafter the upper layer (hexane) was then collected into an amber screw capped vial. An aliquot of the hexane extract was then transferred into a 1 cm³ quartz cuvette and the absorbance taken at 503 nm against the solvent-blank using JENWAY (6405) UV Visible spectrophotometer.

Carotenoid

It was determined following methodology described by (FAO, 1992). 2.5 g of the sample was weighed into conical flask with 30 ml of hexane and 20 ml of ethanol was added again into the conical flask with 2 ml of 2% NaCl. The mixture was thoroughly mixed and the content was transferred into a separating funnel where the filtrate was allowed to stand for about 10 minutes to allow for extraction of carotenoid. The lower content was discarded and the upper layer (extractant phase) was collected. The absorbance was then estimated by using the equation below with spectrometer at 436 nm.

Determination of Moisture content

Ten gram of tomato was chopped into a pre-weighed petri-dish and dried in an oven at 105°C for four hours and then allowed to cool. The petri dish was then weighed. This process was repeated many times until the weight of the petri-dish with its content remained constant. Triplicate determinations was made for each sample (Gharezi et al., 2012). Where:

The weight of empty crucible W_0

Weight of crucible plus samples W_1

Weight of crucible plus oven-dried sample W_2

$$\text{Moisture content \%} = \frac{W_1 - W_2}{W_1 - W_0} \times \frac{100}{1} \quad (3)$$

Determination of Protein

Zero point two gram of each homogenized sample was weighed into the digestion tube followed with the addition of 5 g of Kjeldahl catalyst mixture and 15 cm³ of concentrated sulphuric acid.

The tube was swirled gently until the mixture has thoroughly mixed. The mixture was heated continuously for 2 hr until the solution became clear and 15 cm³ of 40% NaOH was added. The mixture was allowed to cool and then transferred into 100 cm³ volumetric flask and diluted mark with distilled water. Another 10 cm³ of 2% boric acid was measured into 100 cm³ Erlenmeyer flask and few drops of Methyl red indicator was added.

Furthermore, 10 cm³ of digested aliquot was transferred into a distillation apparatus and then distilled into the boric/indicator for 15 min. The distillate was then titrated with 0.025 ml HCl to a pink end point (AOAC, 2005).

Determination of Fat

Petroleum spirit at (40 – 60°C b.pt) was used as reagent. 1 g of tomatoes samples was weighed into fat free extraction thimble and plugged lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250 ml sox-let flask which has been previously dried in oven was cooled in the desiccators and weighed. The sox-let flask was then filled to ¾ of its volume with petroleum ether at boiling point between 40 – 60°C, extractor plus condenser set was placed on the heater for six hours with constant running water from the tap for condensation of ether vapour. The set was constantly watched for ether leaks and the heat source was adjusted appropriately for the ether to boil gently. The ether was left to siphon over several times, at least 10 – 12 times until it was short of siphoning. It was after this; it was noticed that any ether content of the extractor was carefully drained into the ether stock bottle. The thimble containing samples was then removed and dried on a clock glass on the bench top. The extractor flask and condenser was replaced and distillation continues until the flask was practically dry. The flask which now contains the fat or oil was detached, its exterior cleaned and dried to a constant weight in the oven (AOAC, 2005). Thus, if the initial weight of dry sox-let flask is W₀ and the sum of final weight of oven dried flask and fat is W₁, percentage fat was obtained by the following formula:

$$\% \text{ fat} = \frac{W_1 - W_0}{\text{weight_of_sample}} \times \frac{100}{1} \quad (4)$$

Determination of Ash

It was determined following methodology described by (Owusu et al., 2012). Two gram of the chopped tomato sample was placed in a porcelain crucible and ashed in a muffle furnace at 600°C for 3 hr. The crucible was allowed to cool and the weight of the ash was taken. The percentage of ash was calculated using the formula below:

$$\% \text{ ash} = \frac{\text{Weight_of_ash}}{\text{Original_weight_of_sample}} \times \frac{100}{1} \quad (5)$$

Determination of fibre

It was determined following methodology described by (Adebooye et al., 2006). One hundred gram of the chopped sample was weighed into a beaker and 50 cm³ of H₂SO₄ (1.25%) was added. The mixture was then boiled for 1 hour, filtered and the residue boiled with distilled water to dilute the excess acid. 50 cm³ of NaOH (1.25%) was added and the mixture was boiled for another 1 hour. It was then filtered, washed with distilled water until it was free from alkali.

The residue was then rinsed with acetone and dried in oven at 110°C for 2 hr. The dried residue was ashed in a muffle furnace at 600°C for 3 hours, cooled in a desiccator and weighed to obtain the weight as W_1 . The crucible containing white or grey ash (free of carbonaceous material) was cooled in the desiccators and weigh to obtain W_2 . The crude fibre content was calculated by difference in W_1 and W_2 .

The formula below was used to obtained percentage of fibre;

$$\% \text{ fibre} = \frac{W_1 - W_2}{\text{weight_of_sample}} \times \frac{100}{1} \quad (6)$$

Determination of Carbohydrate

The addition of the value obtained from protein, fibre, fat, ash and moisture content minus 100 gives the value of carbohydrate in the sample (AOAC, 2005).

Shelf Life Determination

Shelf life of tomato fruit is the period of time which started from the harvest and extends to the time the sample stayed in storage systems before rotting begins (Gomez et al., 2008). This was calculated by counting day at optimum marketing and eating qualities.

Data Analysis

The collected data on various parameters was statistical analysis using XL stat version 2016 and Minitab version 17 statistical package. Results was statistically evaluated by variance analysis (ANOVA) and statistical differences with p-values under 0.05 was considered significant. Post-hoc test (Duncan multiple tests) was performed to analyse differences among the means of independent observations, to assess the differences between maturity stage, bioactive compounds content, antioxidant activity and also to establish association between various quality and shelf life for tomato cultivar studied. Pearson correlation tests ($p \leq 0.05$) was used to ascertain the existence of linear relationships between variables: (lycopene content/colour, lycopene/antioxidant activity, carotenoid content/antioxidant activity and ascorbic acid/antioxidant activity).

RESULTS and DISCUSSION

The results of the physiological evaluation made on three ripening stage of 'Beefmaster Hybrid VFNASt' tomato fruit cultivars during 18 days of storage are explained using summary and variance analysis as shown in (Tables 2 and 3).

Effect of storage on Weight loss (%)

Tomato ripening stages had significant effect on weight lost, weight loss is one of the key indicators of deterioration, degrading, and lost in the quantity of tomato fruit (Brummell, 2006). In term of ripening stage, light red stage has the highest weight loss (14.35%) followed by (9.58%) pale red and the lowest value (5.4%) was recorded for breaking stage as shown in (Table 2).

Table 2. Summary of the total weight loose (%) of the tomato fruit

Statistics	Ripening Stages		
	Breaking stage	Pale red stage	Light red stage
Mean	5.4 a	9.58 ab	14.36 b
Max	5.95	10.83	17.06
Min	4.43	7.23	9.08
SD	0.85	2.04	4.57
CV (%)	15.66	21.3	31.84

Mean values in the same row with different lower case alphabet are significantly different ($p < 0.05$).

The highest value (14.35%) might be due to the fact that the rate of transpiration and respiration was lower due to higher concentration of CO₂ and lower concentration of O₂ inside the storage system (Ajayi and Oderinde, 2013). The results of these findings was in agreement with the result of (Ali and Thompson, 1998) and (Bhattarai and Gautam, 2006) who reported the loss in weight of tomatoes sample during storage. Significant variation responsible for the lowest weight loss in the storage system was found due to the effect of constant temperature (10°C) in respect of percent weight loss of tomato. However, 5.4% weight loss at breaking stage showed less weight loss as compared to order two ripening stage evaluated in this research work. This shows that tomatoes with lower weight loss can be stored for longer time as compared to other samples.

The statistical analysis shows that there is no significant difference between the weight loss of pale red and breaking and pale red and light red tomato fruit stored but light red significantly higher when compared to breaking ($p < 0.05$). The differences in the weight loss show that breaking stage has the ability to be stored for longer period. This shows that the storage system has favourable storage conditions that can accommodate any of the samples for a period of time in terms of weight loss values as it is mostly lower when compared with other researcher Bhattarai and Gautam (2006) and (Okolie and Sanni, 2012) reports. The table also shows that at the end of the experiment storage method adopted has no significant different on three samples stored when compared to the results obtained at the beginning of the experiment ($p < 0.05$). The result of these findings are in agreement with Bhattarai and Gautam (2006) report. The results reveal that the physicochemical profile of tomato fruits changes significantly over time and with the storage methods as already reported by other researchers (Okolie and Sanni, 2012).

Effect of storage on Firmness (N)

On the basis of objective firmness evaluation, it was found that the minimum acceptable levels or marketability scores of tomato firmness at which an individual tomato fruit could be acceptable for sale at retail level is about 1.45 and 1.46 Nmm⁻¹ respectively (USAD, 2007) which is in conformity with the results obtained in this report. However, this study is similar to the finding of (USDA, 2007) which reported that the firmness values of the tomatoes generally used at home is about 1.28 and 1.22 Nmm⁻¹ acceptability score respectively.

Ripening stage had significant effect on the firmness of the tomato at the end of shelf life in each of the samples studied. The result shows that the highest value of firmness (4.879 Nmm⁻¹) was found at light red stage after 18 days of storage followed by pale red stage (4.76 Nmm⁻¹) and breaking stage (4.522 Nmm⁻¹).

The lowest firmness (4.522 Nmm^{-1}) was found in breaking stage after 18 days as shown in Figure 2. The significant variation in the samples resulted from the combination of different ripening stages of the fruits and some physical variations that occurs during the storage period, this result was in agreement with the results of (Ketelaere et al., 2004).

The results in (Table 3) show that ripening stages caused a slight softening in tomato when compared with less ripe tomato fruits. After 18 days, nearly all the samples stored was still very firm and they had good finger feel firmness for marketing purpose particularly light red ripen stage. After 18 days of storage it was observed that the firmness values of tomato fruits used for this research work was acceptable because it was in conformity with that of 1.31 Nmm^{-1} result of Thompson, (1996).

Significant differences in firmness values was observed for acceptability levels of both samples of tomatoes. Figure 1 shows that firmness values of tomatoes sample were accompanied by decreasing acceptability levels from breaking stage – pale red – light red sample. Firmness values of the three samples decreased as the storage period increases. This reduction was between 9 and 18 days for acceptability level as compared with result of Thompson, (1996). The variation between minimum and maximum values of samples at acceptability levels (very firm) is slightly higher than the variations of other acceptability levels. This variation might be due to some difficulty in categorization, especially in the homogeneity of samples acceptability levels. At the end of the experiment all samples were very firm when touched by hand.

Table 3. Summary of the firmness (N) of the tomato fruit

Storage time	Ripening Stage		
	Breaking stage	Pale red stage	Light red stage
fresh	156.29±19.38 ^{ab}	174.53±41.79 ^a	111.86±16.66 ^{ab}
9 days	103.93±7.65 ^{abc}	64.26±30.39 ^{abc}	71.4±31.48 ^{abc}
15 days	76.16±6.3 ^{ac}	53.55±8.33 ^{ab}	56.33±57.58 ^a
18 days	45.22±8.58 ^{ad}	47.6±11.9 ^{ab}	48.79±1.19 ^a

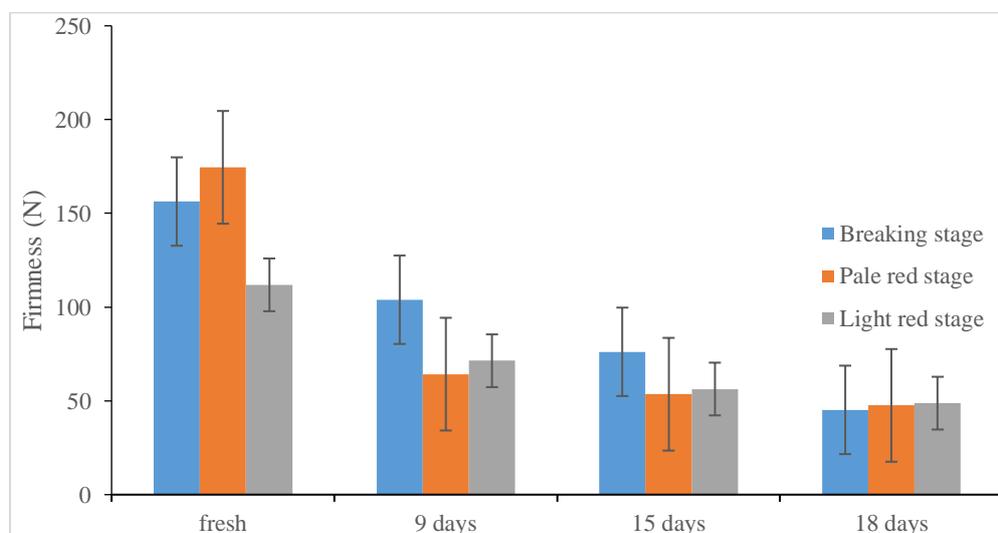


Figure 1. Variation in the firmness of tomato fruits stored under the same storage condition.

Effect of storage Bioactive Compounds and Antioxidant Capacity

It has been shown that skin and seeds are important contributors to the major antioxidant compounds of tomatoes (Toor and Savage, 2006), it is on this note that chemical analyses was performed on whole tomatoes. It is a product that has high value of antioxidant content (Hanson et al., 2004; Rosales et al., 2006). Tomato fruit possess constituents of several molecules with this capability of which lycopene, ascorbic acid and carotenoid was hereby selected. The quantity of these molecules varies along with ripening stages and with the storage methods applied as shows in Table 4, and their results are in agreement with the report of (Valverde et al., 2011; Oms-Oliu et al., 2011).

Effect of storage Vitamin C content (mg/g)

Vitamin C is one of the most important nutritional value parameter in fruits and vegetables (Tigist et al., 2013). The average content of ascorbic acid of the three samples are 1.125 ± 0.0177 breaking, 1.076 ± 0.019 pale red, and 1.293 ± 0.026 light red, mg/g respectively as indicated on Table 4. The value of the three samples are in the lower range when compared to that of reported values (Adebooye et al., 2006; Olaniyi et al., 2010; Adubofuor et al., 2010; Gharezi et al., 2012) which might be due to environmental factors. Thus, it is observed from the result that the concentration of vitamin C follows these sequence, breaking stage < pale red stage but > light red stage, this implies that pale red stage is significantly different from breaking stage and light red stage but breaking stage and light red stage are not significantly different from each other ($p < 0.05$). The results also suggest that, in general, when comparing the ripening stages of tomato fruits, breaking stage and pale red stage are not significantly different from each other but significantly different from light red stage ($p < 0.05$). It is recognized that high levels of acidity are responsible for the stability of vitamin C in breaking stage during storage. Furthermore, phenolic substances have also been linked to the stability of vitamin C due to its protective effect (Ajayi and Oderinde, 2013). These results are consistent with other studies (Dumas et al., 2003; Toor and Savage, 2006). Finally, it was also observed that content of vitamin C increase till the last day of the storage as shows in figure 2.

Table 4. Summary of the Bioactive Compounds and Antioxidant Capacity content (mg/g) of the tomato fruit

Ripening stage	vitamin C		Lycopene		Carotenoid	
	Control	After	Control	After	Control	After
Breaking stage	0.6688 ± 0.0088^a	1.125 ± 0.0177^{ab}	34.34 ± 0.0141^{ab}	64.4353 ± 0.0075^{ab}	0.0963 ± 0.0007^{ab}	0.2996 ± 0.0058^{ab}
Pale red stage	0.7813 ± 0.0619^{ab}	1.0763 ± 0.0194^{ab}	20.7624 ± 0.1731^a	114.021 ± 0.0297^{abc}	0.0877 ± 0.0058^a	0.4383 ± 0.0144^{ab}
Light red stage	1.2688 ± 0.0088^{bc}	1.2938 ± 0.0265^{bc}	73.0984 ± 0.0023^{ab}	133.0066 ± 0.0048^{bc}	0.3272 ± 0.0101^{ab}	0.4056 ± 0.0029^{ab}

Mean values in the same column with different lower case alphabet are significantly different ($p < 0.05$).

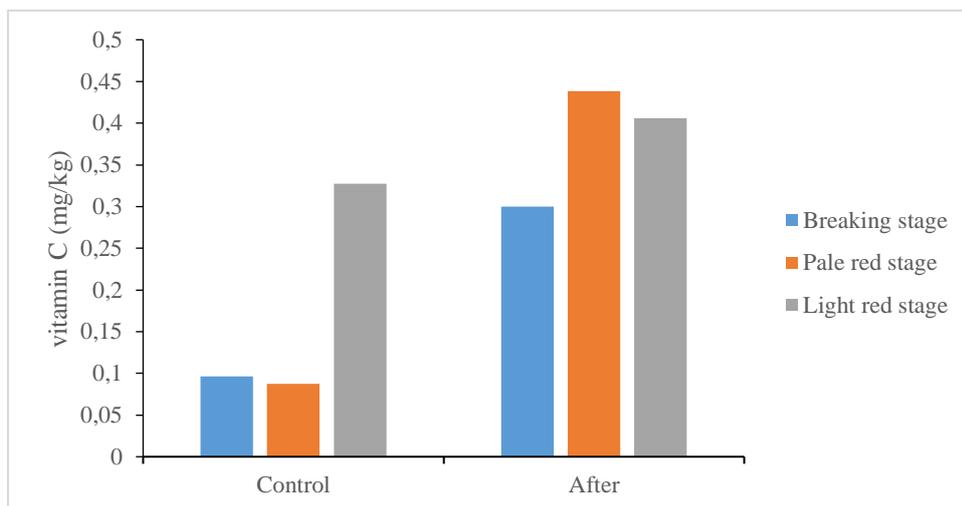


Figure 2. Vitamin C (ascorbic acid) content of tomato fruit at different ripening stages

Effect of storage Lycopene content (mg/kg)

As a major carotenoid in human blood, lycopene protects against oxidative damage to lipids, proteins and DNA. Lycopene is a potent quencher of singlet oxygen (a reactive form of oxygen) which suggests that it may have comparatively stronger antioxidant properties than other major plasma carotenoid. This antioxidant (lycopene) is cancer preventative phytonutrient that also protect the body from damage caused by compounds known as free radicals.

Table 4 shows the concentration level of lycopene in the three samples before and after the experiment and varies accordingly light red stage < pale red stage < breaking stage, this implies that light red stage is significantly different from breaking stage but not significantly different from pale red stage. Breaking stage and pale red stage are not significantly different from each other ($p>0.05$). In general, it was observed from the results that there is a positive change in lycopene concentration with time for the three samples at the end of storage period.

For example, breaking stage exhibited almost 50% higher levels of lycopene after 18 days of storage when compared to control while the rate of increase in pale red and light red stage was 20% and 35% respectively when compared to control as shows in Figure 3. Various values have been previously reported for tomatoes lycopene and the values obtained in this report was in agreement with Malami and Mohammed, (2013); Wawrzyniak et al., (2005) the range of 3.79 - 17.53 mg/100g. At the end of the experiment, a higher antioxidant activity was observed in comparison to the start of the experiment, these results are consistent with the results of Dumas et al., (2003); Toor and Savage, (2006).

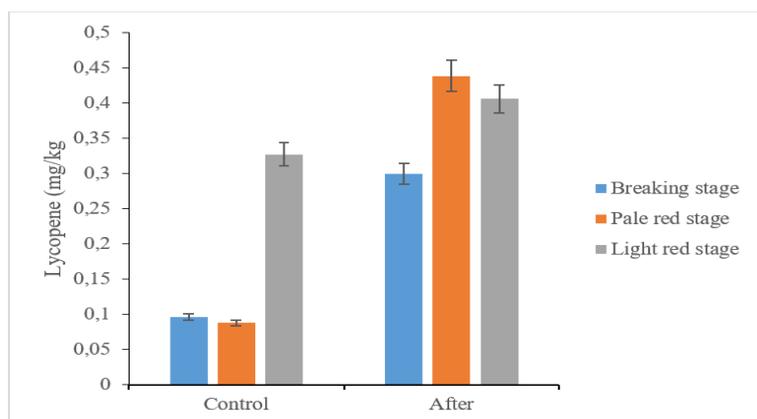


Figure 3. Lycopene content of tomato fruit at different ripening stages

Effect of storage Carotenoid content (mg/kg)

Carotenoid quantity varies as the ripening of the samples varies and this result is similar to the results presented by Valverde et al., (2011) and Oms-Oliu et al., (2011). Table 4 shows difference in the content of carotenoid between the samples before and at the end of the experiment ($p < 0.05$).

Regarding the effect of the storage conditions, carotenoid is expressed mainly in the rate of change of concentrations rather than on their maximum values. This observation is certainly linked with the increased concentrations of lycopene. The influence of storage conditions on the level of carotenoid has already been mentioned by other authors, who reported an increase in carotenoid content between 3.6 and 9.0 mg/100g in tomatoes stored for 14 days (Maul *et al.*, 2000).

However, at the end of these experiment, it was observed that the tomatoes sample stored shows deterioration in their values of bioactive compounds. Since antioxidant activity is related to the contents of carotenoid compounds, it is not surprising that it follows a trend that is parallel with those observed for those samples when compared with control as shows in Figure 4.

Table 5. Summary of proximate composition (%) of the tomato fruits

Ripening stage	moisture content		protein		ash content		crude fibre		carbohydrate		fat	
	Control	after	control	after	control	after	control	after	control	after	control	after
Breaking stage	95.36± 0.16 ^{bc}	91.67± 0.13 ^a	1.04± 0.00 ^b	1.04± 0.00 ^b	0.34± 0.08 ^a	0.82± 0.01 ^{abc}	1.00± 0.00 ^a	1.00± 0.00 ^a	1.75± 0.06 ^a	4.96± 0.15 ^b	0.51± 0.014 ^{ab}	0.51± 0.00 ^{ab}
Pale red stage	95.13± 0.96 ^{abc}	93.05± 0.03 ^{ab}	1.01± 0.00 ^{ab}	1.00± 0.00 ^{ab}	0.36± 0.03 ^{ab}	0.79± 0.02 ^{abc}	1.13± 0.18 ^{ab}	1.00± 0.00 ^a	1.79± 1.11 ^{ab}	3.66± 0.01 ^{ab}	0.59± 0.01 ^b	0.51± 0.01 ^{ab}
Light red stage	93.88± 0.35 ^a	95.51± 0.55 ^{ab}	0.95± 0.00 ^a	0.97± 0.01 ^{ab}	0.43± 0.04 ^{ab}	0.83± 0.00 ^{bc}	1.00± 0.00 ^{ab}	1.00± 0.00 ^{ab}	3.17± 0.38 ^b	1.19± 0.56 ^{ab}	0.58± 0.01 ^{ab}	0.51± 0.01 ^a

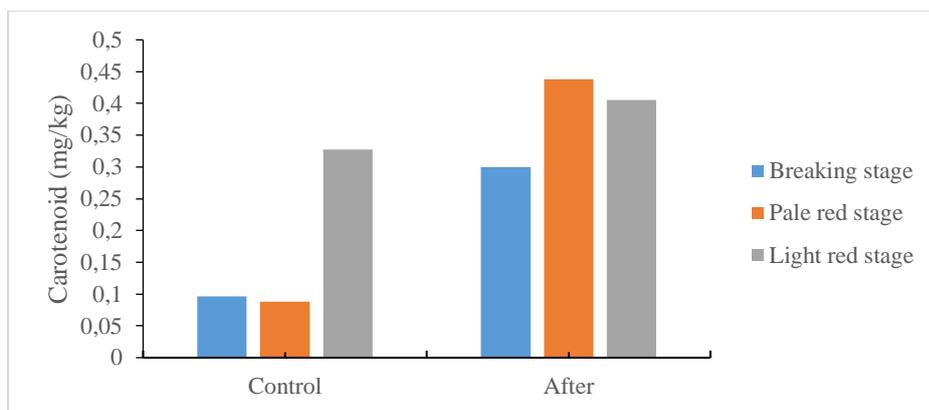


Figure 4. Carotenoid content of tomato fruit at different ripening stage

Proximate Composition Results

Table 5 shows the proximate composition of tomatoes for control and after storage. Mean values in the same column with different lower case alphabet are significantly different ($p < 0.05$). The results of the proximate analysis revealed that in the entire sample, moisture content was higher than other elements analysed and this was in agreement with the findings of Agbemafle et al. (2015); Idah et al. (2010). Table 5 shows the initial level of proximate composition results of tomatoes samples before storage; for breaking stage and pale red stage the value of moisture content (MC) is 95% and light red is 93%, for breaking stage and pale red the value of protein is 1.04 and 1.01% which are not significantly different from each other and the value of protein for light red is 0.95%, for breaking stage, pale red and light red, the value of fat content are 0.51%, 0.59% and 0.58%, for breaking stage and light red the value of crude fibre is 1.00% and pale red is 1.13%, for breaking stage and pale red the value of ash content are 0.34 and 0.36% which is statistically not different from each other and the value of ash content for light red is 0.43% and for breaking stage, pale red and light red stage, the value of carbohydrate is 1.75%, 1.79% and 3.17% respectively. These level of proximate composition was different from the one that was obtained from two varieties of tomatoes, in Ogbomosho local and Ibadan local: 42.55% and 29.39% protein content, 3.72% and 3.86% fat content and 6.94% and 7.42% fibre as reported by Olaniyi et al. (2010). These deviations could be attributed to differences in ecological distribution of the tomato varieties and genetic differences among the varieties.

Moisture content (%)

Since foods with low moisture content have longer shelf life, thus results obtained in Table 5 shows that breaking stage have relatively longer shelf lives compared with pale red and light red. Various levels of moisture content for tomatoes have been previously reported and the results of this report was in agreement with those of Oko-Ibom and Asiegbu (2007); Adubofuor et al. (2010); Hossain et al. (2010) who have reported the moisture content in the range of 88.19 - 90.67%, but higher than those of Adebooye et al. (2006) who reported 78.56%. Figure 6 shows the variation in moisture content as regards the ripening stages. However, the moisture content of 95% for this report is close to the work of Okorie et al. (2004) that reported 93% MC and Idah and Aderibigbe (2005) 92.2% MC of harvested sample of tomatoes before storage. Figure 5 shows the proximate composition of tomatoes for control and after storage.

Protein (%)

The average crude protein content obtained for this research work and the values are in the lower range than the results that was previously reported by Olaniyi et al. (2010). However, the result shows that all the three samples has no significant different when compared with the control at the end of the experiment. Since there was no significant difference among the results obtained for the three samples at the control stage of the experiment, therefore the results are in conformity with USDA (2007) standard for fresh tomatoes. However, tomato Fruits contain a low amount of protein but aged tissues such as overripe fruits usually have a higher amount of non-protein nitrogen as reported by Vincent et al. (2009). Pale red had highest percentage lipid, however, significantly higher than 0.20% as estimated by Idah et al. (2010). The agronomical activities during production as also account for dissimilarity. Fatty acids are very essential in physiological functions of human as they participate primarily to produce hormone-like substances which control blood pressure, blood clotting, the immune response, blood lipid levels and the inflammatory response as reported by Vincent et al. (2009). However, the results show that storage method adopted for the research is the best storage method to be adopted for storing tomato at any ripening stage. Figure 6 shows the behaviours of the samples before and after storage.

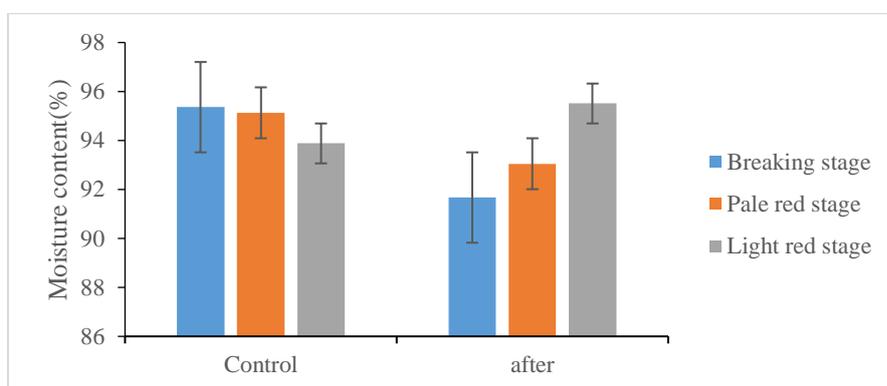


Figure 5. moisture content of tomato fruit at different ripening stage

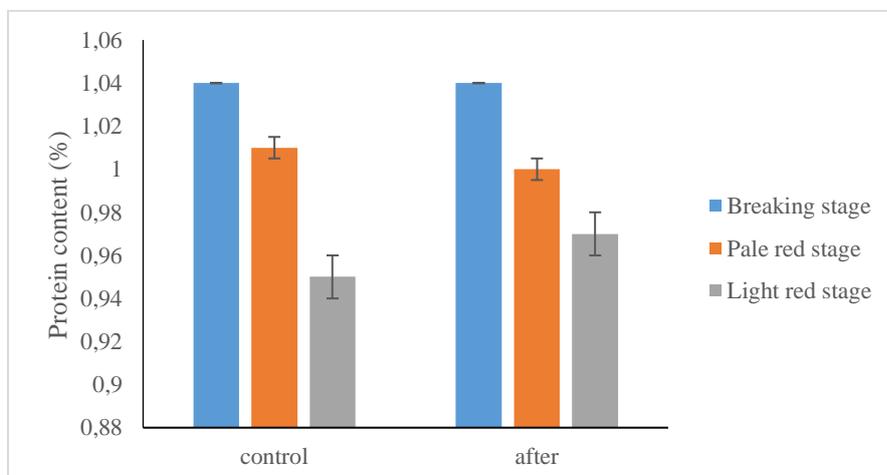


Figure 6. protein content of tomato fruit at different ripening stage

Ash content (%)

The ash content of a food substance depicts the total crude minerals. Light red had the highest ash content (0.43%) at control and the value fall in the range of 0.47% - 0.98% as reported by Agbemafle et al., (2015). Table 5 shows the average ash contents of breaking stage, pale red and light red at control level as 0.34 ± 0.08 , 0.36 ± 0.03 , and $0.43\pm 0.04\%$ ($p < 0.05$) respectively and the results was closely in agreement with the results of Adubofuor et al. (2010); Suleiman et al. (2011) whose reported values ranging from 0.2 – 0.4%. From the results light red, has more ash content and hence contains more mineral than breaking stage and pale red this indicate that the mineral levels was independent of the source. This observation is similar to the findings of Nielsen (2002) who evaluate the nutritional quality of these cultivars and observed that Roma VF (beefmaster tomato) light red ripening stage has more minerals than those of breaking and pale red ripening stage. Plants accumulate these nutrients through absorption by roots in the medium of water, thus this action decreases especially in water-stressed plants as reported by Akinci and Losel (2012). The crude mineral concentrations in fruits are unchanged during the storage except when there are leakages from the tomato fruits and also when they are not metabolized as reported by Hui (2006). The variances in ash content in each samples are as a result of storage methods coupled with the influence of preservatives. Figure 7 shows variance in level of ash content between the three samples (breaking stage, pale red and light red) when compared with the control.

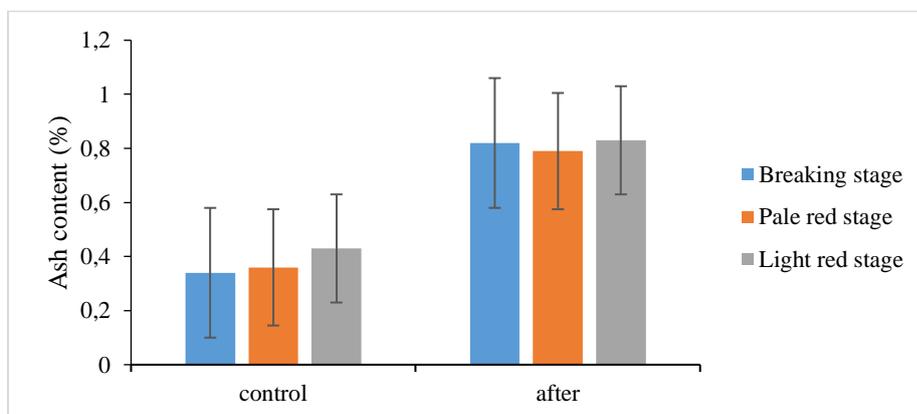


Figure 7. Ash content of tomato fruit at different ripening stage

Crude fibre content (%)

According to the results presented in Table 5, The average levels of crude fiber content in the three samples was found to be, for breaking stage $1.00\pm 0.00\%$, for pale red $1.00\pm 0.00\%$ and for light red $1.00\pm 0.00\%$ respectively ($p < 0.05$). The results obtained at the control for the samples are breaking stage $1.00\pm 0.00\%$, pale red $1.13\pm 0.18\%$ and light red $1.00\pm 0.00\%$ which was within the range of 0.70 – 3.25% when compared with the reports obtained by Onifade et al. (2013); Alvi et al. (2003); Adebooye et al. (2006); Olaniyi et al. (2010). All samples used contain a considerable amount of fibre in varying quantities. Onifade et al. (2013) reported that the percentage of crude fibre in Yoruba variety of tomato was 2.50%, comparatively higher than the similar variety used in this current study.

The principal components of dietary fibres are lignin, cellulose, hemicelluloses, pectins, resistant starch and non-digestible oligosaccharides. The cell wall makes up to 1% to 2% of the fresh weight of fruits and cellulose constitutes about 33% of that amount Vincent et al. (2009). Brummell (2006) reported that the quantity of cellulose fluctuates during fruit ripening. Dietary fibre is an indigestible component of food that enhances peristaltic movement of bowels. It prevents constipation as well as colon cancer as reported by Terry et al. (2001). The crude fibre values were found to vary widely alongside with the samples as shown in Figure 8. Regarding the effect of the storage methods, it is expressed mainly in the rate of change of concentrations rather than on their maximum values. However, in comparing all the results with control, all the samples perform best because is not significant different from control ($p < 0.05$).

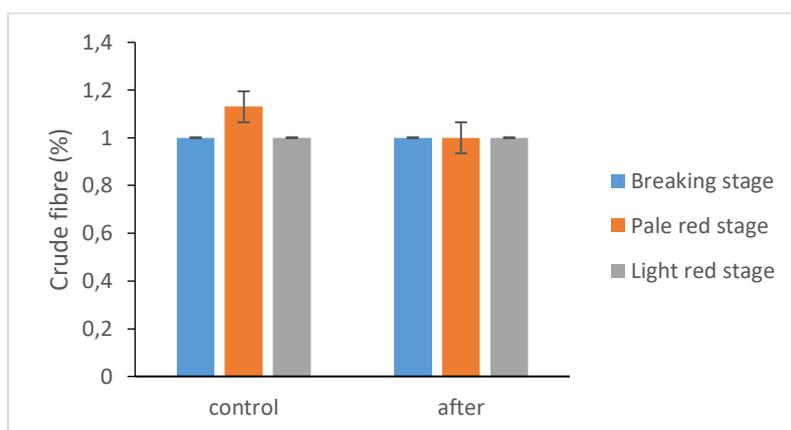


Figure 8. Crude fibre content of tomato fruit at different ripening stage

Carbohydrate content (%)

Carbohydrate is an essential nutrient in the body as it is the major energy source in the body. The range of carbohydrate content of all the samples used was 0.48% – 4.96% higher than 1.0% - 3.90% as reported by USDA (2007) as shows in Table 5. The differences may be as a result of varietal influence, environmental conditions and other agronomical practices during production Agbemafle et al. (2015). The differences in carbohydrate content can also be attributed to storage methods employed which may have differential effects on the activities of cell wall enzymes such as α -galactosidase, β -galactosidase, β -mannosidase and β -glucosidase. These are also responsible for the rotting and softening of the tomato fruit Emadeldin et al. (2012).

The amount of carbohydrate is second to moisture in all the samples as shows in Table 5. It was observed that there is interplay between the moisture and carbohydrate contents without the influence of storage methods. This assertion was supported by Idah et al. (2005) that the percentages of moisture and carbohydrate are increasing and decreasing respectively as the storage period increasing as shows in figure 9. In figure 9, the results obtained for breaking stage perform better more than other two samples and the result is in conformity with USDA (2007) reports. With respect to storage methods, significant differences were recorded in all the samples. The storage method significantly enhanced the carbohydrate content of tomato stored over the control in all the samples except light red.

The control, however, showed significantly higher value of moisture and fibre contents when compared to other reports. The results indicated that the use of the storage method adopted promoted higher values of carbohydrate.

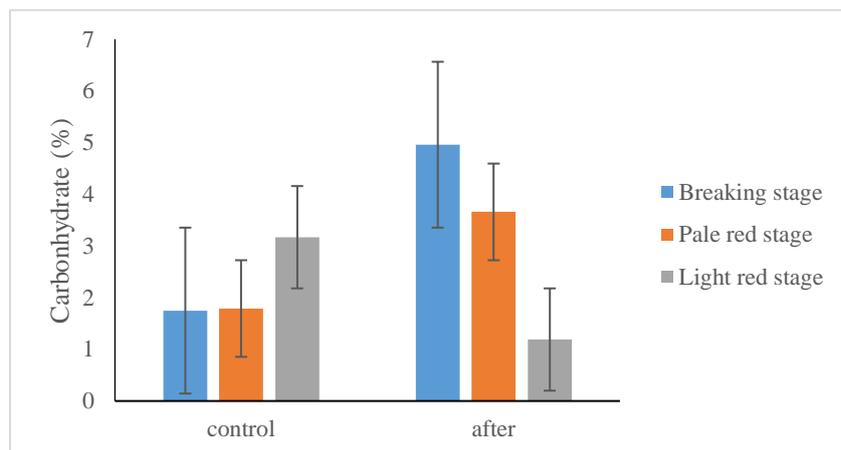


Figure 9. carbohydrate content of tomato fruit at different ripening stage

Fat content (%)

Fat is one of the most important nutritional value parameter in tomato fruits as reported by Tigist et al. (2013). The fat content at control level was from 0.51% (breaking stage), 0.59 % (pale red) to 0.58% (light red). These values are in agreement with the concentration of fat as reported by Ochoa-Velasco et al. (2016), but less than findings of Vinha et al. (2012); Kelebek et al. (2017).

In this report it was found that fat content during storage for the samples reduces at the end of the storage as shows is Figure 10. Moreover, we could conclude that decreases significantly ($p \leq 0.05$) depend on tomato variety and storage methods adopted. The values recorded for the fat content are 0.51% breaking stage, 0.51% for pale red and 0.51% for light red. The fat content in all the samples decreases at the end of storage period and the decreases was 0.02% less compared with the control level of the experiment. Similarly, Ajayi and Oderinde (2013) observed the same decrease in fat content. Table 5 shows that fat content values obtained in this report is higher when compared with USDA (2007). As we all known that light red is the one that is commonly marketed. It was found that at this stage (light red) the values of fat content is 0.51%. The light red colour is a little more overripe more than pale red at the beginning of the experiment. Tomatoes which reached the red colour stage (light red) might have had a long overall storage time or might have stayed on the vine too long. Variation in fat content of the samples (breaking stage, pale red and light red) readings range between maximum and minimum values increased at the end of storage time. The fat content increased with increasing maturation (Batu, 1995). It is interesting to note that in this report that modern storage has enhanced the shelf-life of all the samples, recording the highest shelf life in modern storage.

This finding was supported by the results of Idah et al. (2005) who reported that evaporative cooler system (pot-in-pot) was a promising storage mechanism that enhanced the shelf life of fruits and vegetables which operate in the same principle as modern storage. However, with some careful modifications in modern storage system, preserving fruits and vegetables will be more effective in the rural areas in Nigeria.

Shelf life (days)

The shelf life of tomato fruits was significantly influenced by the storage methods applied. 18 days was recorded as the maximum shelf life at the end of storage period. Storage systems had significant effect on the shelf life of tomato. There was a significant variation among the samples resulted from the combination of different ripening stage in respect of shelf life of tomato.

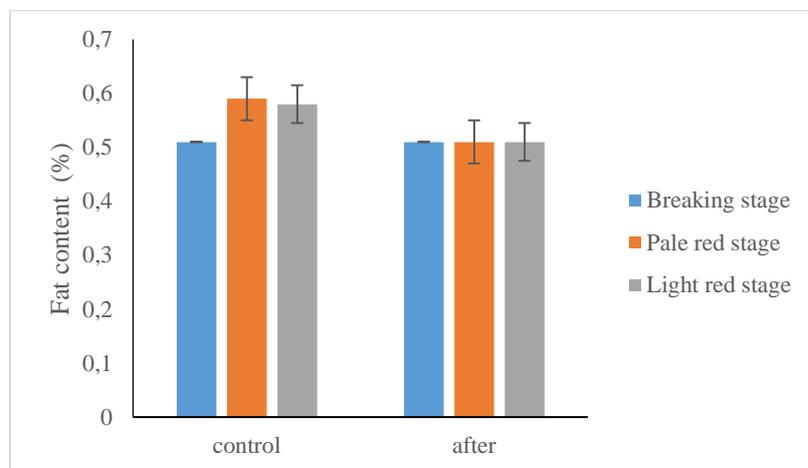


Figure 10. Fat content of tomato fruit at different ripening stage

CONCLUSION and RECOMMENDATION

In conclusion, this research work demonstrates the effect of storage time on physiological and proximate composition parameters of three ripening stage of tomato fruits namely, breaking stage, pale red and light red. At the end of storage period, physiological parameters were the most affected during storage period and the concentrations of the antioxidant compounds (lycopene content) increased over time in all analyzed samples and the storage method adopted maintain optimal selected physiological properties and proximate composition profiles. All the samples analysed had the most extended shelf-life and has the highest nutritional values. Since the firmness values of samples obtained in this research are above 1.28 Nmm^{-1} and 1.46 Nmm^{-1} before and after storage, this shows that they are suitable for easily marketable in the supermarket and even for marketing. In order to improve the post-harvest handling and nutritional qualities of tomatoes fruits it is recommended from this study that modern storage method (refrigeration conditions) should be used and tomato fruits should be harvested at breaking stage to help the handlers and storage of tomato for at least few weeks before it gets to processing or final users with little variation in the quality.

REFERENCES

- Adebooye, O.C., Adeoye, G.O & Tijani-Eniola, H. 2006. Quality of fruits of three varieties of tomato (*Lycopersicon esculentum (L) Mill*) as affected by phosphorus rates. Journal of agronomy, 5,3, 396-400.
- Adubofuor, J., Amankwah, E.A., Arthur, B.S & Appiah, F. 2010. Comparative study related to physico-chemical properties and sensory qualities of tomato juice produced from oranges, tomatoes and carrots. African journal of food science, 4,7, 427-433.

- Agbemafle, R., Owusu-Sekyere, J.D & Bart-Plange, A. 2015. Effect of deficit irrigation and storage on the nutritional composition of tomato (*Lycopersicon esculentum* Mill. cv. *Pectomech*). Croatian journal of food technology, biotechnology and nutrition 10,1-2, 59-65.
- Ajayi, I.A, & Oderinde, R.A. 2013. Effects of different home storage conditions and preservation on some chemical constituents of tomato (*Lycopersicon esculentum*). Journal of applied chemistry, 4, 4, 19–29.
- Akinci, S. & Losel, D.M. 2012. Plant water-stress response and mechanisms. In Rahman, M. I., (ed): Water stress. Intech, shanghai. 1-30.
- Ali, B. & Thompson, K. 1998. Effect of modified atmosphere packaging on postharvest qualities of pink tomatoes. Tr. Journal of Agricultural and forestry. 22, 365 – 372.
- Alvi, S.S., Khan, K.M., Sheikh, M.A. and Shahid, M. (2003). Effect of peeling and cooking on nutrients vegetables. Pakistan journal of nutrition, 2,3, 189-191
- AOAC International. 2005. Official methods of analysis. Maryland, USA: AOAC International.
- Batu, A. & Thompson, A.K., 1993. Effects of cross-head speed and probe diameter on instrumental measurement of tomatoes firmness. In Proceedings of the International Conference for Agricultural Machinery and Process Engineering, October, Seoul, Korea 1340–1345, 19–22.
- Beckles, D.M. 2011. Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. Postharvest Biology and Technology, 63, 1, 129–140
- Bhattarai, D.R & Gautam, D.M. 2006. Effect of harvesting method and calcium on post-harvest physiology of tomato. Nepal Agric. Res. J. 7, 37 – 41.
- Brummell, D.A. 2006. Cell wall disassembly in ripening fruit. Functional Plant Biology 33, 103-119.
- Chapagain, P.B. & Wiesman, Z. 2004. Effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of greenhouse tomato. Scientia Hort., 99, 279-288.
- Dumas, Y., Dadomo, M., Lucca, G. & Grolier, P. 2003. Effects of environmental factors and agricultural techniques on antioxidant content of tomatoes. J. Sci. Food Agric., 83, 369-382. <http://dx.doi.org/10.1002/jsfa.1370>.
- Emadeldin, H.E.K., Mathilde, C. & Mireille, F. 2012. Cell wall glycosidase activities and protein content variations during fruit development and ripening in three texture contrasted tomato cultivars. Saudi Journal of Biological Science 19,3, 277-283.
- FAO 1992. Manuals of food quality control: chemical analysis. Food and Agricultural Organization, Rome.
- Fish, W.W., Perkins-Veazie, P. & Collins, J.K. 2002. A quantitative assay for lycopene that utilizes reduced volumes of organic solvents. Journal of Food composition and Analysis, 15, 309-317
- Gharezi, M., Joshi, N. & Sadeghian, E. 2012. Effect of postharvest treatment on stored cherry tomatoes. Journal Nutrition and Food Sciences, 2, 8, 157-167.
- Gomez, K.A. & Gomez, A.A. 1984. Statistical procedure for agricultural research, second edition. John Willey and sons, New York, 28-92
- Hanson, P.M., Yang, R.Y., Wu J., Chen, J.T., Ledesma, D. & Tsou, S.C.S. 2004. Variation for antioxidant activity and antioxidants in tomato. J. Amer. Soc. Hort. Sci., 129, 5, 704-711. Retrieved from <http://journal.ashspublications.org/content/129/5/704>
- Harvey, T & Chan, J.R. 1983. Handbook of tropical foods. Marcel Dekker Inc. New York & Basel.

- Henry's 2018. The Henrys' Plant Farm, 2018 tomato variety list, Horticultural Science journal, 1-7.
- Hossain, M.M. E., Alam, M.J., Hakim, M.A. & Amanullah, A.S.M. 2010. An assessment of physico chemical properties of some tomato genotypes and varieties grown at Rangpur, Bangladesh Res. Pub. J. 4, 3, 135-243.
- Hui, Y.H. 2006. Handbook of fruits and fruit processing. Blackwell Publishing professional, Iowa, USA. 36-37.
- Idah, P.A. & Aderibigbe, B.A. 2005. Quality changes in dried tomatoes stored in sealed polythene and open storage systems. Proceedings of Dept of Agricultural Engineering, Federal University of Technology, Minna Niger State, Nigeria.
- Junqueira, A.H., Peetz, M.S. & Onoda, S.M. 2011. Um modelo de inovação na gestão da cadeia de produção e distribuição de hortaliças diferenciadas no Brasil. ESPM, Central de cases. Disponível em: http://www.organicnet.com.br/wp-content/uploads/sweet_grape.pdf
- Kader, A.A. 2008. Perspective: flavor quality of fruits and vegetables. Journal of the Science of Food and Agriculture. 88, 1863-1868.
- Kelebek, H., Sellic, S., Kadiroglu, P., Kola, O., Kesen S., Ucar B. & Çetiner B. 2017. Bioactive compounds and antioxidant potential in tomato pastes as affected by hot and cold break process. Food Chemistry, 220, 31–41.
- Ketelaere, B.J., Lammertyn, G., Molenberghs, M., Desme, B., Nicolai, J. & Baerdemaeker, J. 2004. Tomato cultivar grouping based on firmness change, shelf life and variance during postharvest storage. Postharvest Biology and Tech. 34,2, 187-201
- Malami, D.J. & Mohammed, M.I. 2013. Effect of heat treatment on the lycopene content of tomato Puree. ChemSearch Journal, 4,1, 18-21.
- Maul, E., Sargent, S.A., Sims, C. A., Baldwin, E.A., Balaban, M.O. & Huber, D.J. 2000. Tomato flavor and aroma quality as affected by storage temperature. J. Food Sci., 657, 1228-1237. <http://dx.doi.org/jfsv65n7p1228-1237ms19990912>
- Melkamu, M., Seyoum, T. & Woldetsadik, K. 2008. Effects of pre post-harvest treatments on changes in sugar content of tomato, African Journal of Biotechnology 7,8, 1139– 1144.
- Nielsen, S.S. 2002. An Introduction to the Chemical Analysis of Food. Satish Kumar Jain for CBS Publishers and Distributors, 459611-A, 11 Darya Ganj, New Delhi (India). 83-175
- Nkansah, G.O., Owusu, E.O., Bonsu, K.O. & Dennis, E.A. 2003. The effect of mulch types on growth, yield and fruit quality of tomato (*Lycopersicon esculentum* Mill.). Ghana Journal of Horticulture, 2, 55-63.
- Ochoa-Velasco, C.E., Valadez-Blanco, R., Salas-Coronado, R., Sustaita-Rivera, F., Hernández-Carlos, B., García-Ortega, S. & Santos-Sánchez, N.F. 2016. Effect of nitrogen fertilization and *Bacillus licheniformis* biofertilizer addition on the antioxidants compounds and antioxidant activity of greenhouse cultivated tomato fruits (*Solanum lycopersicum* L. var. Sheva). Scientia Horticulturae, 201, 338–345.
- Oko-Ibom, G.O. & Asiegbu, J.E. 2007. Aspects of tomato fruit quality as influenced by cultivar and scheme of fertilizer application,” Journal of Agriculture, Food, Environment and Extension, 6, 1, 71–81.
- Okolie, N.P. & Sanni, T.E. 2012. Effect of post-harvest treatments on quality of whole tomatoes. Afric. J. Food Sci., 6, 3, 70-76. <http://dx.doi.org/10.5897/AJFS11.188>.
- Okorie, S.U., Nwanekezi, E.C. & Okor, O.O. 2004. The quality properties of tomatoes (*Lycopersicon esculentum*) as influenced by processing with a chemical preservative and storage. Nigeria Food Journal, 22, 195-197. ISSN 0189-7241
- Olaniyi, J., Akanbi, W., Adejumo, T. & Akande, O. 2010. Growth, fruit yield and nutritional quality of tomato varieties. African Journal of Food Science, 4,6, 398- 402.

- Olympio, N. S. & Kukuaih, S. 2002. Preliminary evaluation of post-harvest response of Tomato fruits to soil liming with Calcium Hydroxide. *Ghana Journal of Horticulture*. 1, 102-107
- Oms-Oliu G., Hertog M. L. A. T. M., Van de Poel, B., Ampofo-Asiama, J., Geeraerd, A.H. & Nicolai, B.M. 2011. Metabolic characterization of tomato fruit during pre-harvest development, ripening, and postharvest shelf-life. *Postharvest Biol Technol*, 62, 7-16. <http://dx.doi.org/10.1016/j.postharvbio.2011.04.010>
- Onifade, T.B., Ajayi, A.O., Aregbesola, O.A. & Ige, M.T. 2013. Some physical properties and thin layer drying characteristics of local varieties of tomatoes (*Lycopersicon lycopersicum*). *Agriculture and Biology Journal of North America* 4, 3, 275-279.
- Owusu, J., Haile, M. Wang, Z. & Amisshah, A. 2012. Effect of drying methods on physicochemical properties of pretreated tomato (*Lycopersicon esculentum mill.*) slices. *Journal of Food Technology, Biotechnology and Nutrition* 7, 1-2, 106-111.
- Raffo, A., Leonardi, C., Fogliano, V., Ambrosino, P., Salucci, M., Gennaro, L., Bugianesi, R., Giuffrida, F. & Quaglia, G. 2002. Nutritional value of cherry tomatoes (*Lycopersicon esculentum* Cv. Naomi F1) harvested at different ripening stages. *Journal of Agricultural and Food Chemistry* 50, 6550- 6556.
- Rosales, M.A., Ruiz, J.M., Hernandez J., Soriano T., Castilla N. & Romero L. 2006. Antioxidant content and ascorbate metabolism in cherry tomato exocarp in relation to temperature and solar radiation. *J. Sci. Food Agric.*, 86, 1545-1551. <http://dx.doi.org/10.1002/jsfa.2546>
- Siddiqui, M.W. 2015. Postharvest biology and technology of horticultural crops – principles and practices for quality maintenance. USA, 572.
- Suliman, A.E., Awini, K.M.A. & Yousif, M.T. 2011. Suitability of some tomato (*lycopersicon esculentum Mill.*) genotypes for paste production. *Journal of Science and Technology* 12, 2, 45-51.
- Terry, P., Giovannucci, E., Michels, K. B., Bergkvist, L., Hansen, H., Holmberg, L. & Wolk, A. 2001. Fruit, vegetables, dietary fiber and risk of colorectal cancer. *Journal of National Cancer Institute* 93, 525-533.
- Thompson, A.k. 1996. Post-harvest technology to fruits and vegetables. Black well science led. Ox-ford. UK, 410
- Tigist, M., Workneh, T. S. & Woldetsadik, K. 2013. Effects of variety on the quality of tomato stored under ambient conditions. *Journal of Food Science and Technology*, 50, 3, 477–486.
- Toor, R.K. & Savage, G P. 2006. Antioxidant activity in different fractions of tomatoes. *Food Research International*, 38, 487–494.
- Tovionen, P. M. A. 2007. Fruit maturation, ripening and their relationship to quality. *Stewart postharvest review*, 3, 2 1-5
- USDA 2007. The US and World Situation: Fresh and Processed tomatoes. USDA Foreign Agricultural Services Horticultural and Tropical Products Division. <http://www.fas.usda.gov/http/2007%20Tomatoes.pdf>
- USDA 2007. National Nutrient Data Base for Standard Reference. *USDA-ARS Nutrient Data Laboratory Home Page*. Available online: http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/list_nut_edit.pl
- Valverde-Queralt, A., Medina-Remón, A., Andres-Lacueva, C. & Lamuela-Raventos, R.M. 2011. Changes in phenolic profile and antioxidant activity during production of diced tomatoes. *Food Chemistry*, 126, 1700–1707.

- Vincent, A.R., Manganaris, G.A., Sozzi, G.O. & Crisosto, C. H. 2009. Nutritional quality of fruits and vegetables. In Florkowski, W. J., Shewfelt, R. L., Brueckner, B. and Prussia, S. E. (editors). *Postharvest Handling: A Systems Approach*. Second Edition. Elsevier Inc. Academic Press
- Vinha, A. F., Soares, M. O., Herdeiro, M. & Machado M. 2012. Chemical composition and antioxidant activity of Portuguese diospyrus kaki fruit by geographical origins. *J. Agric. Sci.*, 4, 2, 281-289. <http://dx.doi.org/10.5539/jas.v4n2p281>
- Wawrzyniak, A., Marciniak, A. & Rajewska, J. 2005. Lycopene content of selected Foods available on the Polish market and estimation of its intakes. *Polish Journal of Food and Nutrition Sciences*, 14, 55, 195- 200.
- Wills RBH, W.B. McGlasson, D., Grahnam, TH. Lee. & Hall, E.G. 2004. *Postharvest. An introduction to the physiology and Handling of Fruits and Vegetables*. Granada Publishing Ltd. London. 24.