International Food Research Journal 25(3): 1126-1132 (June 2018)
Journal homepage: *http://www.ifrj.upm.edu.my*

# Quality attributes of tomato powder as affected by different pre-drying treatments

[1*]Aderibigbe, O.R., [1]Owolade, O.S., [1]Egbekunle, K.O., [1]Popoola, F.O. and [2]Jiboku, O.O.

[1]*National Horticultural Research Institute, Product Development Programme, P.M.B. 5432, Idi-Ishin, Jericho GRA, Ibadan, Oyo State, Nigeria*
[2]*Moshood Abiola Polytechnic, Department of Science Laboratory Technology, Abeokuta, Ogun State, Nigeria*

**Article history**

*Received: 19 January 2017*
*Received in revised form: 20 March 2017*
*Accepted: 22 March 2017*

**Keywords**

*Tomato powder*
*Pre-drying treatments*
*Quality*

**Abstract**

Production of tomato powder by drying of tomatoes can help to reduce postharvest losses; however, maintaining the quality of the powder may be challenging. In order to improve the quality of tomato powder, fresh tomato slices were exposed to different pre-drying treatments: 2% sodium benzoate, 2% calcium chloride and 0.25% sodium metabisulphite. The quality of the tomato powder produced after drying and blending was studied. Pre-treatment with sodium benzoate improved the protein, ash, fiber, total soluble solids, lycopene, vitamin C and colour of tomato powder better compared to pretreatment with calcium chloride and sodium metabisulphite. Sodium metabisulphite treated powder retained the highest amount of carbohydrate while fat was highest in the powder without any treatment. In conclusion, pre-drying treatments have the potential to enhance the quality of tomato powder.



## Introduction

Tomato *(Lycopersicon esculentum)* as a vegetable and fruit occupy an important place in healthy daily diet. Tomato and its products are excellent source of minerals, vitamins and antioxidants. It is rich in vitamin C and antioxidant such as lycopene, carotenes and phenolics (Giovanelli and Paradiso, 2002). The consumption of beta-carotene and lycopene, which are available in tomato has been linked to lower incidence of cardiovascular disease and prostate cancer (Ishida and Chapman, 2004; Rao and Rao, 2007).

Nigeria produces about 6 million tons of tomatoes annually (Idah *et al.*, 2007). However, many (20-50%) of these produce are lost after harvest (FAO, 1977; Olorunda and Aworh 1983; Nwajiuba, 2002). Post-harvest losses in horticultural fruit crops are mainly related to handling, from harvest to retail. Losses are caused by mechanical injuries, inadequate storage, unsuitable handling and transport, and on-display time in the retail market (Ferreir *et al.*, 2005). The major step towards achieving a greater level of food increase and security therefore is to prevent food losses between harvest and consumption. Tomatoes can be processed into different forms and preserved for longer periods.

Tomato has several downstream products such as puree, ketch-up and juice; these products are sold in stores throughout the country thereby making tomato available all year round. However, these products require high cost technology for development of good quality products. The development of low cost and community adaptable preservation methods will be beneficial to farmers and consumers. Sun-drying is one of the most economical methods of food preservation. Sundried tomato powders have become a choice ingredient in developed countries and is commonly used in the food service segment (CSD, 1997). However, the maintenance and consistency of quality of sun-dried tomato powder is challenging; hence the need for pre-treatments. The aim of this study, therefore, was to access the quality attributes of tomato powder as influence by different treatments before sun-drying.

## Materials and Methods

### *Preparation of the raw material*

Mature and ripe tomatoes (royal variety) were bought from Sasha market, a popular tomato market in Ibadan, Oyo-State, Nigeria. The tomatoes were sorted to remove the damaged ones, washed in a clean water and weighed. The tomatoes were then subjected to hot water blanching for 3-5 minutes and were allowed to cool afterwards. The blanched

*Corresponding author.
Email: *connecttolaide@yahoo.com*

tomatoes were cut into small slices (one cm in length) using sharp sterilized stainless steel knives.

*Pre-drying treatments of tomato slices*

The tomato slices were divided into four and treated as follows: (a) Dipping in 2% Sodium benzoate ($C7H_5NaO_2$) solution at room temperature for 5 min. (b) Dipping in 2% Calcium chloride ($CaCl_2$) for 5 min. (c) Dipping in 0.25% Sodium metabisulphite ($Na_2S_2O_5$) for 5 min. (d) This served as the control; tomato slices were not subjected to any pre-treatment.

*Dehydration/drying of Tomato Slices*

The tomato slices were spread on perforated stainless steel trays (34 cm wide, 50 cm long and about 5 cm height. Tomato slices were loaded on perforated stainless steel trays and was allowed to sun-dry.

*Preparation of tomato powder*

The dried tomato slices were collected and ground using clean household grinder and stored in sealed plastic containers prior to further analysis.

*Proximate analysis*

The moisture content, protein, fat, ash, total fibre and carbohydrate contents of the samples were determined by the method of AOAC (2000).

*Analysis physicochemical properties*

Total soluble solids (TSS) were determined for each sample according to AOAC (2005) method using an Atago DR-A1digital refractometer (Atago Co. Ld., Japan) at 25°C and expressed as percentage. Titratable acidity (TA) was obtained by titrating 5 ml of tomato powder with 0.1 N NaOH up to pH 8.1. The result was expressed as grams of citric acid per 100 g of dry tomato weight.

The pH was measured using Hanna pH meter at ambient temperature 27±.0 5. Five grams of the raw material and equivalent weight in grams of the soluble matter in the raw material of tomato dried powder considering moisture content differences, The samples were dissolved in 50 ml distilled water and filter through Whatman filter paper No.1. Then the pH of the samples was measured in triplicates.

*Determination of lycopene content*

Lycopene estimation was done by using (AOAC, 1990). 5 to 10 g sample was repeatedly extracted with acetone until the residue became colorless. The acetone extract was transferred to a separating funnel containing 10 to 15 ml petroleum ether and then 5% sodium sulphate solution was added. The lower acetone phase was repeatedly extracted with petroleum ether similarly, until it became colorless. The upper petroleum ether extract was pooled and its volume was made up to 50 ml with petroleum ether and the color was measured in a 1 cm cell at 503 nm in spectrophotometer (Systronics UV-VIS double beam spectrophotometer 2201) using petroleum ether as blank. The results are reported as;

$$\text{Lycopene content (mg/100g sample)} = \frac{3.1206 \times A \times D \times 100}{1 \times W \times 1000}$$

Where, A = absorbance at 503 nm; D = dilution of extract to 100 ml; W = weight of sample taken.

*Colour measurement*

Color of tomatoes and dried products were measured by hunter color difference meter (Color Quest XE, Hunter Lab), calibrated with a white tile. "L" represents the lightness index ("0" for black to "100" for white), "a" represents greenness and redness ("+100" for red and "-80" for green) while, "b" represents for yellowness and blueness ("+70" for yellow and "-80" for blue). Three replications of each of the five tomato varieties were analyzed in triplicate.

*Determination of total carotenes*

About 0.2 -0.3 g of chopped and homogenous samples were extracted with cold Acetone which was later partitioned with petroleum ether. The ether phase was passed through Neutral Alumina (activity III) packed column. The column was eluted with petroleum ether and the first band was collected into 25 ml volumetric flask. The extract was read at 450 mm and total carotenoid content calculated are as follows;

$$C\ (\mu g/g) = \frac{A \text{ x Volume (ml) x } 104}{A^{1\%} \text{ x 1cm x sample weight (g).}}$$

Where A = Absorbance, $A^1$ % = absorption coefficient of –carotene in PE (2592) (Rodriguez-Amaya and Kimura 2004).

*Determination of ascorbic acid (Vitamin C) content*

About 5 ml of standard solution of ascorbic acid was pipetted into 100ml conical flask. 10ml of oxalic acid was added and the solution titrated against the dye (V1 ml) until a pink colour persisted for 15 seconds. The dye consumed is equivalent to the amount of ascorbic acid. Also, 0.5 g of the sample was extracted in 4% oxalic acid and made up to 100ml. The solution was filtered. 10 ml of oxalic acid was added to 5 ml of the filtrate above. The solution was then titrated against the dye solution (2, 6 – dichlorophenol indophenol). The volume of dye used was recorded as (V2 ml) (Ibitoye, 2005).

$$\text{Ascorbic acid (mg/100g)} = \frac{0.5\ \text{mg} \times V2 \times 100\ \text{ml} \times 100}{V1 \times 5\ \text{ml} \times W}$$

Where W = sample weight

*Microbial counts*

The microbial contamination was estimated by analyzing microbial load in tomato powder by using Nutrient Agar(NA) for bacteria and Martins Rose Bengal Agar (MRBA) for mould count following the dilution pour plate method. $10^{-2}$, $10^{-3}$ and $10^{-4}$ were the three dilutions used for analyzing bacteria and mould. The microbial assays were carried within one week of production of the tomato powder.

*Statistical analysis*

Determinations were done in triplicates and all data were subjected to analysis of variance (ANOVA) and the mean separated using Duncan's multiple range test (DMRT) using Statistical Package for Social Sciences (SPSS) version 18.0.

## Results

Tomato slices were dried to a stable moisture content (<10% wet basis) after three days. The result showing the effect of pre-treatments on proximate composition of sun-dried tomato powder is presented in Table 1. The moisture content of fresh tomato slices was 91.00% while that of tomato powder under different pre-treatments ranged between 8.27% - 8.87%. The protein, carbohydrate, fat, ash and fiber content of tomato powder was significantly ($p<0.05$) higher than fresh tomatoes. Among tomato powder pretreated before drying, the ones pretreated with sodium benzoate had the highest protein, ash and fiber content (25.67±0.61, 3.00±0.1, 35±0.47 respectively) compared to those pretreated with calcium chloride (protein=23.24±0.23, ash=2.20±0.10, fibre=33.00±0.46) and sodium metabisulphite (protein=24.43±0.12, ash=2.02±0.01, fiber=33.93±0.21). However, carbohydrate content was highest in the one pretreated with sodium metabisulphite (CHO=11.89±0.06) and fat was highest in the one pretreated with calcium chloride (fat=21.53±0.45). Tomato powder that was not exposed to any pre-drying treatment had lower nutrients (protein=22.40±0.26, CHO=11.20±0.10, ash=2.55±0.05 and fiber=33.61±0.40) than those exposed to pretreatment except for fat content.

Table 2 displays the effect of pre-treatments on physico-chemical properties of tomato powder. The pH value of the fresh tomato (3.85±0.15) was significantly lower than tomato powder pretreated with sodium benzoate, calcium chloride, and sodium metabisulphite (4.07±0.11, 4.10±0.10, and 4.00±0.00 respectively). But, there was no significant difference in the pH of tomato powder under different pretreatments. The TA and TSS of tomato powder pretreated with sodium benzoate (1.30±0.20 and 4.10±0.00) were significantly higher than those pretreated with calcium chloride (0.89±0.04 and 4.00±0.00) and sodium metabisulphite (0.88±0.04 and 4.00±0.00). The titratable acidity of tomato powders increased significantly ($p<0.05$) compared to fresh tomatoes while total soluble solids decreased in tomato powders compared to fresh tomato.

Table 3 shows the effect of pretreatments on lycopene, carotene and vitamin C content of tomato powder. The lycopene content of tomato powder under different pretreatment (13.70 mg/100g, 10.13 mg/100g, and 11.91 mg/100g for sodium benzoate, $CaCl_2$ and sodium metabisuphite respectively) was significantly ($p<0.05$) higher than that of fresh unprocessed tomatoes (9.60mg/100g). Following the same trend as reported for lycopene, the total carotene content of tomato powder under different pretreatment (1.70 mg/100g, 1.50 mg/100g, and 1.56 mg/100g for sodium benzoate, $CaCl_2$ and sodium metabisulphite respectively) was significantly ($p<0.05$) higher than that of fresh unprocessed tomatoes (1.33 mg/100g). The reverse was the case for vitamin C; it reduced significantly in tomato powder as compared to fresh unprocessed tomato but, pretreatment retained more vitamin C in the tomato powder (29.93 mg/100g, 28.59 mg/100g, and 27.45 mg/100g for sodium benzoate, $CaCl_2$ and sodium metabisulphite respectively) when compared to tomato powder that was pretreated at all (20.5 mg/100g).

Table 4 represents the effect of pretreatments on colour attributes of tomato powder. The mean $a^*/b^*$ values were significantly higher for tomato powder pretreated with sodium benzoate (0.69) as compared to those pretreated with $CaCl_2$ (0.39), sodium metabisulphite (0.34) and control (0.32). Microbial population of tomato powder reduced drastically compared to fresh tomatoes (Table 5). Tomato powder made from tomatoes pretreated with sodium benzoate had the lowest microbial load compared to pretreatment with calcium chloride and sodium metabsulphite. No mould growth was observed in tomato powders that were pretreated with sodium benzoate, calcium chloride and sodium

Table 1. Proximate composition (g/100g) of fresh tomato and tomato powder under different pretreatments

| Treatments | Moisture | Protein | Carbohydrate | Fat | Ash | Fiber |
|---|---|---|---|---|---|---|
| Fresh tomato | 91.00 ± 0.50$^{a}$ | 1.28 ± 0.08$^{a}$ | 2.89 ± 0.68$^{a}$ | 0.97 ± 0.26$^{a}$ | 0.89 ± 0.07$^{a}$ | 2.97 ± 0.60$^{a}$ |
| $C_7H_5NaO_2$ | 8.27 ± 0.21$^{b}$ | 25.67±0.61$^{b}$ | 7.39 ± 1.22$^{b}$ | 20.60 ±0.53$^{b}$ | 3.00 ± 0.11$^{b}$ | 35.63 ±0.47$^{b}$ |
| $CaCl_2$ | 8.87 ± 0.15$^{b}$ | 23.48 ± 0.23$^{c}$ | 11.17 ± 0.32$^{c}$ | 21.53 ±0.45$^{cb}$ | 2.20 ± 0.10$^{c}$ | 33.00 ±0.46$^{c}$ |
| $Na_2S_2O_5$ | 8.47 ± 0.31$^{b}$ | 24.43 ±0.12$^{d}$ | 11.89 ± 0.06$^{cd}$ | 19.43 ± 0.40$^{d}$ | 2.02 ± 0.07$^{c}$ | 33.93 ±0.21$^{cd}$ |
| Control | 8.40 ± 0.10$^{b}$ | 22.40 ±0.26$^{e}$ | 11.20 ± 0.10$^{cd}$ | 21.96 ± 0.27$^{c}$ | 2.55 ± 0.05$^{d}$ | 33.61 ±0.40$^{cd}$ |

Any two Mean ± SD values that do not carry similar superscript in a column are significantly different ($P \leq 0.05$) according to DMRT.
$C_7H_5NaO_2$, Sodium benzoate; $Cacl_2$, Calcium Chloride; $Na_2S_2O$, Sodium metabisulphite.

Table 2. Physico-chemical properties of fresh tomato and tomato powder under different pretreatments.

| Pretreatments | pH | TA(%) | TSS (%) |
|---|---|---|---|
| Fresh tomato | 3.83 ± 0.15$^{a}$ | 0.85 ± 0.04$^{a}$ | 4.25 ± 0.01$^{a}$ |
| $C_7H_5NaO_2$ | 4.07 ± 0.11$^{b}$ | 1.30 ± 0.20$^{b}$ | 4.10 ± 0.00$^{b}$ |
| $CaCl_2$ | 4.10 ± 0.10$^{cb}$ | 0.89 ± 0.04$^{a}$ | 4.00 ± 0.00$^{c}$ |
| $Na_2S_2O_5$ | 4.00 ± 0.00$^{ab}$ | 0.88 ± 0.04$^{a}$ | 4.00 ± 0.00$^{c}$ |
| Control | 4.13 ± 0.05$^{b}$ | 1.25 ± 0.05$^{b}$ | 4.00 ± 0.00$^{c}$ |

Any two Mean ± SD values that do not carry similar superscript in a column are significantly different ($P \leq 0.05$) according to DMRT.
$C_7H_5NaO_2$, Sodium benzoate; $Cacl_2$, Calcium Chloride; $Na_2S_2O$, Sodium metabisulphite.

metabisulphite. The bacterial load observed in tomato powders under pretreatments was within safe limits (ICMS, 2002).

## Discussion

This study reports the quality attributes of tomato powder exposed to chemical treatments before drying. Pre-treatment with sodium benzoate, calcium chloride and sodium metabisulphite before drying has resulted in producing tomato powder with satisfactory quality and nutritive value. Drying tomatoes into powder form reduced the moisture content drastically and concentrated the nutrients present in tomatoes. A moisture content of 8.27% - 8.87% reported in the present study is similar to that obtained by (Jayathunge *et al*., 2012) in study on a development of a methodology for production of dehydrated tomato powder and the acceptability of the product. The high moisture content in fresh tomato slices predisposes it to microbial attack and eventual spoilage. Sun-drying was effective in reducing the moisture content of tomato powders significantly ($p<0.05$) to below 10%. The increased nutrient in tomato powder compared to fresh tomato suggests that drying does not only extend the shelf life of tomatoes but also concentrate the nutrient contents.

Titratable acidity has been shown to increase with drying (Owusu *et al*., 2012); the same was reported in the present study. The increase in titratable acidity with drying may be due to the organic acids in tomato becoming more concentrated. Titratable acidity and pH are interrelated in terms of acidity, but have different impacts on food quality. While titratable acidity impacts more on the flavour and taste quality of products pH gives a measure of the strength of the acid in food (Underhill, 1989). Lower pH confers more protection against microbial growth (Sadler and Murphy, 2010). The decreased total soluble solids observed in dried tomato powders as compared to fresh tomatoes is similar to that reported by Owusu *et al.* (2012) but different from that reported by Ashebir *et al.* (2009). However, the dry tomato slices in Ashebir study were not subjected to pre-treatments before drying.

Carotene and lycopene content of tomato powder increased compared to fresh tomato. This is not consistent with the result of Adubofuor *et al.* (2010) who reported a reduction in carotene content of tomato juice as compared to fresh unprocessed tomato. Though, increase in temperature is thought to cause

Table 3. Lycopene, vitamin c and carotene content of fresh tomato and tomato powder under different pretreatments

| Pretreatments | Lycopene (mg/100g) | Vitamin C (mg/100g) | Total Carotene (mg/100g) |
|---|---|---|---|
| Fresh tomato | 9.60 ± 0.19[a] | 40.50 ± 2.18[a] | 1.33 ± 0.10[a] |
| $C_7H_5NaO_2$ | 13.70 ± 0.18[b] | 29.93 ± 0.12[bc] | 1.70 ± 0.06[b] |
| $CaCl_2$ | 10.13 ± 0.18[c] | 28.59 ± 0.51[abc] | 1.50 ± 0.02[c] |
| $Na_2S_2O_5$ | 11.91 ± 0.13[d] | 27.45 ± 0.42[ab] | 1.56 ± 0.04[c] |
| Control | 11.1 ± 0.14[e] | 20.5 ± 0.50[cb] | 1.66 ± 0.02[bc] |

Any two Mean ± SD values that do not carry similar superscript in a column are significantly different (P≤0.05) according to DMRT.
$C_7H_5NaO_2$, Sodium benzoate; $Cacl_2$, Calcium Chloride; $Na_2S_2O$, Sodium metabisulphite.

Table 4. Colour attributes of tomato powder under different pretreatment

| Pretreatments | L* | a* | b* | a/b* |
|---|---|---|---|---|
| $C_7H_5NaO_2$ | 27.01 ± 0.02[a] | 6.65 ± 0.28[a] | 9.61 ± 0.01[a] | 0.69 ± 0.03[a] |
| $CaCl_2$ | 45.42 ± 1.19[c] | 7.14 ± 0.01[b] | 17.90 ± 0.01[b] | 0.39 ± 0.00[b] |
| $Na_2S_2O_5$ | 49.88 ± 0.06[b] | 6.79 ± 0.03[a] | 19.85 ± 0.04[c] | 0.34 ± 0.00[c] |
| Control | 46.44 ± 0.02[c] | 5.41 ± 0.01[c] | 17.01 ± 0.08[d] | 0.32 ± 0.00[c] |

Any two Mean ± SD values that do not carry similar superscript in a column are significantly different (P≤0.05) according to DMRT.
$C_7H_5NaO_2$, Sodium benzoate; $Cacl_2$, Calcium Chloride; $Na_2S_2O$, Sodium metabisulphite.

reduction in carotene content of tomato products, the blanching that the tomatoes were exposed to before drying could have played a significant role in the retention of this nutrient.

Loss of Lycopene is dependent on the drying technique. Destruction of Lycopene is also affected by blanching tomatoes prior to drying. Gupta and Nath (1984) reported that the blanched samples had higher lycopene content than the unblanched samples. Processing of food may improve the bioavailability of lycopene and hence its concentration by breaking down cell walls, which weakens the bonding forces between lycopene and tissue matrix, thus making lycopene more accessible and enhancing the cisisomerization (Maguer and Shi, 2000). Lycopene is a carotenoid with good health benefit. It is present in a very limited number of fruits and vegetables. The most common sources of lycopene are tomato, watermelon, pink guava, pink grapefruit and apricot (Rao and Agarwal, 1999). Tomato and processed tomato products are source of lycopene. Lycopene is one of the most efficient quencher of free radicals and singlet oxygen species and has a potent role in the protection of various diseases (Woodall *et al.*, 1997).

Ascorbic acid losses during drying are results of oxidative heat damage (Igwemmar *et al.*, 2013); this influences the nutritional status of tomato powder. The body needs vitamin C to remain in proper working condition. Ascorbic acid is important in

Table 5. Bacterial and mould counts ($10^{-2}$cfu/g) of fresh tomato and tomato powder under different pretreatments

| Pretreatments | Bacterial counts (($10^{-2}$cfu/g) | Mould counts ($10^{-2}$cfu/g) |
|---|---|---|
| Fresh tomato | 20.33 | 6.00 |
| $C_7H_5NaO_2$ | 3.66 | NG |
| $CaCl_2$ | 7.33 | NG |
| $Na_2S_2O_5$ | 6.55 | NG |
| Control | 10.00 | 2.50 |

NG, No growth
$C_7H_5NaO_2$, Sodium benzoate; $Cacl_2$, Calcium Chloride; $Na_2S_2O$, Sodium metabisulphite.

the proper function of the immune system. As an antioxidant, it reacts with compounds like histamines and peroxides to reduce inflammatory symptoms. Its antioxidant property is associated with the reduction of cancer incidences (Lupulescu, 1990).

The value $a^*/b^*$ is commonly used as an index to report the colour quality (brightness of red colour) of tomato (Shi *et al.*, 1999). This variation in redness may be due to effect of sodium benzoate on lycopene content. Colour is an important factor in the consumer preference of tomatoes and tomato products (Žnidarčič *et al.*, 2003). Tomato colour development may be described as two linked parallel processes; the breakdown of green components, mainly chlorophyll, and the synthesis of red components, mainly lycopene (Batu, 2003). Since colour is critical in consumer preference, the effect of chemical pretreatment prior to any dehydration techniques must be taken into consideration.

Microbiological quality is a common criterion used to determine the acceptability and shelf life of dehydrated plant based products. Pre-treatments stopped mould growth in tomato powder. The reduction in moisture content after drying increases storage stability of dried products (Jajathunge *et al*., 2012).

## Conclusion

Sun-drying is a simple technology for dehydrating tomatoes and it has been confirmed to enhance the quality performance of tomato powder. Pretreatment with chemicals can further enhance the quality of tomato powder. The present study showed that sodium benzoate was better as compared to calcium chloride and sodium metabisulphite in retaining more nutrients, maintaining colour and reducing microbial load of tomato powder produced by sun-drying. Further studies are required to test the sensory qualities and acceptability of pretreated tomato powders.

## References

A.O.A.C. 1990. Official Methods of Analysis. 17th ed. Vol. 2. Washington, D.C.: Association of official Analytical Chemist

A.O.A.C. 2000. Official Methods of Analysis. 15thed. Vol. 2. Washington, D. C.: Association of official Analytical Chemist

Adubofuor, J., Amankwah, E.A., Arthur, B.S. and Appiah F. 2010. Comparative study related to physico-chemical properties and sensory qualities of tomato juice and cocktail juice produced from oranges, tomatoes and carrots. African Journal of Food Science 4(7): 427- 433.

Ashebir, D., Jezik, K., Weingartemann, H. and Gretzmacher, R. 2009. Change in colour and other fruit quality characteristics of tomato cultivars after hot-air drying at low final-moisture content. International Journal of Food Science and Nutrition 60(7): 308-315.

Aworh, O.C. and Oluranda, A.O. 1983. Effect of packaging on mechanical damage of perishable fruits. Proceedings of the International Horticultural Society, Ibadan – Nigeria.

Dzivama, A.U., Lawal, A.A. and Saidu, M.J. 2012. Development and Performance Evaluation of Packaging Method for Fresh Tomato in Borno State, a Semi-Arid Environment. Proceedings of the National Conference and Annual Meeting of Nigerian Institution of Agricultural Engineers. 33: 422-427.

Ferreira, M.D., André, T.O.F., Ricardo, F.K., Antonio. C.O., Sylvio, L.H. and Marcelo, T. 2005. Post-harvest quality of fresh-marketed tomatoes as a function of harvest periods. Scientific Agriculture (Piracicaba, Braz.) 62(5): 446-451.

FAO, 1977. (Food and Agriculture Organization). Analysis of an FAO survey of post-harvest crop losses in developing countries. AGPP MISC/27 p.148-149.

Giovanelli, G. and Paradiso, A. 2002. Stability of dried and intermediate moisture tomato pulp during storage. Journal of Agriculture and Food Chemistry 50: 7277-7281.

Gupta, R.G. and Nath, N. 1984. Drying of tomatoes. Journal of Food Science and Technology 21: 372 – 376.

Ibitoye, A.A. 2005. Basic methods in Plant analysis. Concept IT and educational consults, p 6-7. Akure, Nigeria.

ICMSF, 2002. (International Commission on Microbiological Specifications for Foods). Microorganisms in Food 7. Microbiological Testing in Food Safety Management. Kluwer Academic/Plenum, NY.

Idah, P.A., Ajisegiri, E.S. and Yisa, M.G. 2000. Fruits and Vegetables Handling and Transportation in Nigeria. AU Journal of Technology 10(3): 175-183.

Igwemmar, N.C., Kolawole S.D. and Imran I.A. 2013. Effect of heating on vitamin C content of some selected vegetables. International Journal of Scientific and Technology Research 2(11): 209-212.

Ishida, B.K. and. Chapman, M.H. 2004. A comparison of carotenoid content and total antioxidant activity in catsup from several commercial sources in the United States. Journal of Agriculture and Food Chemistry 52: 8017-8020.

Jajathunge, K.G.L.R., Kapilarathne, R.A.N.S., Thilakarathne, B.M.K.S., Fernado, M.D., Palipane, K.B. and Prasanna, P.H.P. 2012. Development of a methodology for production of dehydrated tomato powder and study of the acceptability of the product. Journal of Agricultural Technology 8(2): 765-773.

Johnson, E. J. 2002. The role of carotenoids in human health. Nutrition in Clinical Care 5: 56–65.

Lupulescu, A. 1993. The Role of Vitamins A, B Carotene, E and C in Cancer Cell Biology. International Journal of Vitamin and Nutrition Research 63: 3-14.

Mijinyawa, Y. 2006. Farm Structures. Role and challenges in meeting needs of the Nigerian Farmer. Proceedings NIAE 28: 15-22.

Maguer, M. and Shi, J. 2000. Lycopene in tomatoes, chemical and physical properties affected by food processing. 4th ed. p. 293-294 Chapman and Hall, NY.

Nwajiuba, C.U. 2002. Food Insecurity: An Overview. In Nwajiuba C. (ed). Perspectives on Food Security in Eastern Nigeria. Farming and Rural Systems Economics, Volume 46. Margraf Verlag, Weirkeisheim, Germany.

Opadokun, J.S. 1996. Packaging and Storage Structures for Fruits and Vegetables. Proceeding of Agricultural

Extension and Research Liaison Services. National Crop Protection Workshop P. 72-81.

Owusu, J., Ma, H., Wang, Z. and Amissah, A. 2012. Effect of Drying Methods on Physicochemical Properties of Pretreated Tomato (lycopersicon esculentum mill.) Slices 7 (2): 106-111.

Rodriguez-Amaya, D.B. and Kimura, M. 2004. Harvestplus Handbook for Carotenoid Analysis.

Rao, A. and Agarwal, S. 1999. Role of lycopene as antioxidant carotenoid in the prevention of chronic diseases: a review. Nutrition Research 19: 305-323.

Rao, A. and. Rao, L. 2007. Carotenoids and human health. Pharmaceutical Research 55: 207-216.

Woodall, A., Lee S.W.M., Weesie, R. and Jackson, M. 1997. Britton G. Oxidation of carotenoids by free radicals: relationship between structure and reactivity. Biochimica et Biophysica Acta (BBA) - General Subjects 13(36): 33-42.

Sadler, G. D. and Murphy, P. A. 2010. PH and titratable Acidity. In Nielson, S. S. (Ed): Food Analysis. P. 219-238. New York, USA: Spring.