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Properties and Microbial Load Diversity of Whole and Broken (*nkuwa*) Tomatoes (*Lycopersicum esculentum*) Sold at Different Market Locations in Umuahia Metropolis

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Abstract

Tomato transportation in Nigeria is without mindful of their postharvest spoilage that results in nutritional losses, microbial contamination and their health implications. Broken (*nkuwa*) tomatoes, a major cause of food-borne illnesses, were often patronized by the local food vendors and low income earners because they are cheaper. Physicochemical, phytochemical properties and microbial loads of whole and *nkuwa* tomatoes sold at different market locations within Umuahia metropolis were analysed with standard analytical methods. Three samples of whole and *nkuwa* tomatoes from each market collected at two weeks intervals were used. Results of the whole and *nkuwa* tomato samples increased respectively in colour (178.68-203.77 and 174.95-202.83), pH (4.18-4.45 and 4.57-4.86), tannin (0.78-0.94 and 1.09-1.15 mg/100g), bacteria (8.02-10.53 and 11.02-18.04 cfu/mlx10^5) and fungal (10.03-19.54 and 19.54-28.34 cfu/mlx10^5) loads. Their TTA (5.44-5.39 and 5.54-5.51) flavonoid (36.77-33.61 and 33.68-33.46 mg/100g), phenol (1.39-1.38 and 1.44-1.43 mg/100g), lycopene (14.37-14.33 and 13.96-13.85 mg/100g) and oxalate (1.53-1.51 and 1.45-1.43 mg/100g) decreased. Properties and microbial loads were actually affected by distance from the source of bulk purchase.

1. Introduction

Tomato (*Lycopersicum esculentum*) is one of commercially valuable fruits consumed by man either fresh or processed into varieties of products **(Effiuwevwere, 2000; Onwuka, 2014)**. The consumption has recently increased significantly because of their taste, affordability accessibility and excellent source of nutrients vital for human health and well-being **(Behravesh *et al.*, 2006; Eni *et al.*, 2010)**. Besides, nutrition policies have strongly recommended consumption of more than 400 g/day in a diet **(FAO/WHO, 2004)**. Tomatoes have tasty, easily digestible, juicy and fleshy endocarp with bright colour that stimulates appetite **(Effiuwevwere, 2000)**.

Tomatoes have different varieties with same compositional characteristics **(Bhowmik *et al.*, 2012)** and different colors (green, yellow, orange or red) depending on their stage of maturity. Their red color indicates full maturity stage which is due to carotenoids synthesized during its maturation **(Zeb and Mehmood, 2004)**. The ripening of tomato is characterized by softening of fruit, degradation of chlorophyll as well as synthesis of acids, sugars and lycopene, a form of β-carotenoid pigment and a powerful antioxidant. Nutritionally, tomato is very rich in vitamins, minerals, dietary fibre **(Wogu and Ofuase, 2014)**, and lycopene **(Onuorah and Orji, 2015)**. Antioxidant capacity of lycopene is 1.16 times higher than β-carotene and 2.9 times higher than vitamin C (L-ascorbic acid) **(Arnao *et al.*, 2001)**. Lycopene, beta carotene, and vitamin E are effective antioxidant that inactivate free radicals, slows the progression of atherosclerosis, and prevents colorectal and pancreatic cancers **(Bhowmik *et al.*, 2012)**.

Tomato which is succulent with about 80% moisture content, low pH, rich nutrients and sugars is a good medium for microbial growth **(Muhammad *et al.*, 2004)**. In most developing countries like Nigeria, microbial infestation of tomatoes can occur during the harvesting period, post harvest, handling, storage, transportation and processing **(Barth *et al.*, 2009)**. During transportation from the North to the South, tomatoes are compressed and bruised due to poor transport conditions, like bad roads, types of trucks, baskets and their stacking. Also, during retailing, they are displayed uncovered on tables and baskets in the open markets to attract customers **(Baiyewu *et al.* (2007)**. In most cases tomatoes are washed with dirty water by the retailers. All these give the opportunistic microorganisms room to colonize the tomatoes thereby making poor handling practices more likely to transmit diseases **(Oranusi *et al.*, 2013)**.

All the spoilage due to fungi bacteria fungi, yeast and moulds) and enzymes **(Seema, 2015)** result to changes in taste, smell, appearance, texture or yield **(Onuorah and Orji, 2015)**, reduction in market values and nutritional qualities **(Omolaran *et al.*, 2016)**. More acidic tissues are generally attacked by fungi, while fruits having pH above 4.5 are more commonly attacked

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by bacteria **(Mamta and Shashi, 2017)**. Contaminated tomatoes are the major causes of food-borne illnesses **(Guyader and Atmar, 2008)** which are harmful when consumed without proper cooking in foods **(Valadez *et al.*, 2012)**. Food-borne illnesses are common in developing countries where food standards, regulations and safety polices are not well established or in seldom practice **(WHO, 2007; De-Sousa, 2008)**. Fungi are major sources of potential health hazard to humans because they produce mycotoxins that are capable of causing mycotoxicoses in man following ingestion or inhalation **(Baker, 2006)**. Fungi are the source of tomato spoilage than bacteria **(Ghosh, 2009)**. Bacteria spoil more *nkuwa* than whole tomatoes due to higher pH **(ICMSF, 2005; Bartz *et al.*, 2009)**.
A study on the microbial loads of whole tomatoes sold in three popular markets in Ilorin, Kwara State, Nigeria showed that bacteria counts ranged from 4.00×10^6 - 7.50×10^6 cfu/ml, while the fungal counts ranged from 1.60×10^6 - 3.50×10^6 cfu/ml **(Agbabiaka *et al.*, 2015)**. Several bacteria have been isolated from *nkuwa* tomatoes in Benin City and Lagos state, Nigeria as their major cause of their spoilage. They include among others as *Bacillus subtils*, *Klebsiella aerogenes*, *Pseudomonas aeruginosa*, *Salmonela typhi*, *Proteus mirabilis*, *Escherichia coli* and *Staphylococcus aureus* **(Ogundipe *et al.*, 2012; Wogu and Ofuase, 2014)**. **Barth *et al.* (2009)** also isolated some fungi like *Fusarium oxyporum, Fusarium muniliforme, Aspergillus niger and Rhizopus stolonifer* from soft rotten tomatoes and observed that fungal species destroy tomatoes more than bacterial.
Due to high rate of tomato post harvest spoilage during retail handling which results in food-borne illnesses upon consumption, this study therefore aimed at exploring the physicochemical, phytochemical and microbial loads of whole and *nkuwa* tomatoes sold in three major markets within Umuahia metropolis.

2. Material and methods

2.1 Sources of raw materials

Both whole and *nkuwa* tomatoes (Plates 1-6) used in this study were purchased from Ubani (11 Km from Umuahia), Isigate (center of Umuahia) and Orie-ugba (3.1 Km from Umuahia) markets, all within Umuahia metropolis. Each sample was randomly purchased from three different tomatoes vendors in each market to give a true representation for each market. A total of 6 samples of whole and *nkuwa* tomatoes were obtained. The samples were each packaged separately in sterile Ziploc bag and placed inside coolers containing ice blocks. The samples were transported to the laboratory for analyses within 24 h at about 4 to 7^{o}C to slow down microbial growth and spoilage.

Plate 1: Whole tomatoes from Ubani

Plate 2: *Nkuwa* tomatoes from Ubani

Plate 3: Whole tomatoes from Isigate

Plate 4: *Nkuwa* tomatoes from Isigate

Plate 5: Whole tomatoes from Orie-ogba

Plate 6: *Nkuwa* tomatoes from Orie-ugba

2.2 Sample Preparation

Preparation of tomato samples
Whole and *nkuwa* tomato samples from each market were separately milled with variable speed kitchen electric blender (Philips, Model HR2001/70/AC 220-240V) into their respective fine pastes and packaged in an air-tight transparent bottle for analyses.

2.3 Analyses

2.3.1 Physicochemical

pH
The method described by **AOAC (2010)** was used and the pH of the diluted samples was read with the pH meter.

Titratable acidity
Titration method described by **AOAC (2010)** was used with 1 ml of phenolphthalein indicator. The sample mixtures were separately titrated against standard solution of sodium hydroxide (0.25 N) until pink colour persisted for about 10 to 15 sec for complete neutralization.

Color intensity
The method of **Okwunodulu *et al.*, (2015)** was used. 1 g of the tomato sample was diluted with 50 ml of distilled water, filtered and absorbance of the filtrate taken with UV-VIS spectrophotometer at 550 nm absorbance.

2.3.2 Phytochemical

Phenol
Folin-Ciocalteu reagent method reported by **Odabasoglu *et al.* (2004)** was used. Total phenolic content was calculated as Gallic acid equivalents (GAE) in mg/g of each sample of tomato paste with the aid of the standard curve graph plotted with the equation $y = 0.007x + 0.186$, where $R^2 = 0.992$.

Flavonoid
Method of **Okwu and Omodamiro (2005)** was used and percent flavonoid was calculated thus:

$$\% \text{ Flavonoid} = \frac{\text{weight of residue}}{\text{Weight of sample}} \times \frac{100}{1}$$

Tannin
The method of **AOAC (2010)** was used. One ml of $NaCO_3$ and Folin Denis reagent was added to the tomato samples extracts in the beaker and allowed to settle. Thereafter, the readings were taken using a spectrophotometer. Tannin was calculated as follows:

$$\% \text{ Tannin} = \frac{A_n}{A_s} \text{ x C x } \frac{100}{W} \text{ x } \frac{V_f}{V_a}$$

Where: An= absorbance of test sample
As = absorbance of standard sample
C = concentration of standard solution
Vf = Total volume of extract
Va = volume of extract analyzed
W = Weight of sample

Lycopene
Lycopene was determined using the method described by **Fadupin *et al.* (2012)**. Lycopene standard solution was prepared with 5 mg/ml hexane from where the working mixtures of various concentrations were made by appropriate combination and dilution with hexane. Lycopene content of the tomato samples was measured spectrophotometrically at 503 nm after extraction with hexane. Concentration of lycopene was derived using the molar extinction coefficient of 17.2×10^4 and also by applying the following equation:

Lycopene content (µg/g) = (A503 – 0.0007) x 30.3/g tissue
Where A: Absorbance.

2.3.3 Microbial load

Sample preparation
Test samples were prepared using the method of **Falegan and Oluwaniyi (2015)**. Ten (10) grams of each tomato sample was diluted in warm (50°C) sterile diluents-buffered peptone water (90 ml) to make primary dilution of 10^{-1}, which was incubated at ambient temperature for 2-3 h. Then a series of dilution up to 10^{-5}dilution factor was prepared by transferring the primary dilution (1 ml) into test tube containing the sterile diluents (9 ml), to obtain 10^{-2} dilution and the operation was repeated with sterile diluents (9 ml) using the 10^{-2} and further diluted to obtain 10^{-3}, 10^{-4} and 10^{-5}.

2.3.4 Total microbial load

Pour plate count method using nutrient agar and malt extract were used to determine total bacteria count and total fungi count respectively. A millilitre of 10^{-2} and 10^{-3} dilutions of each pre-prepared test samples was transferred into well labelled sterile petri-plates in duplicates and then overlaid with sterile warm (45°C) 15 ml of respective nutrient media. The plates were carefully swirled for uniform mixing and inoculums distribution. The mixture was allowed to solidify, then inverted and incubated aerobically at 37°C for 72 h. The plates having more than 30 and/or fewer than 300 colonies were selected and counted using colony counter. The total bacteria count (TBC) and total fungi count (TFC) were obtained by multiplying the number of colonies by the dilution factor and was recorded in Colony Forming Unit per millilitre (CFU/ml) **(Olutiola *et al.*, 2000)**.

2.4 Statistical analysis

Mean data of all the samples obtained in this study were statistically analysed using One-way analysis of variance of a completely randomized design with the Statistical Package of Social Sciences version 23.0. Treatment means were separated using Duncan multiple range test at 95 % confidence level ($p<0.05$).

3. Results and Discussion

3.1 Physicochemical properties

The results are shown in Table 1.

Titratable acidity (TTA)

The TTA of whole tomato sample from Ubani market (5.42) was significantly ($p<0.05$) lowerthan 5.44 from Isigate but higher than 5.39 from Orie-ugba. These variations could be traced to the distance between them, degree of bruises before transportation and the extent of handling damages within the three the market locations by the retailers. The more severe the handling practices, the higher the TTA may be because of more microbial contamination **(Barth *et al*., 2009)** and resident time for more degradation of acidic tissues by bacteria **(Mamta and Shashi, 2017)**. Conversely, there was no significant ($p>0.05$) TTA variation between all the *nkuwa* samples of all the market locations. This may mean that the handling activities never had any significant ($p>0.05$) impact.

Table 1 Physicochemical properties of whole and *awarawa* tomato samples

Samples	TTA (%)	Colour intensity	pH
WU	5.42^{ab}±0.02	178.68^{e}±0.02	4.18^{a}±0.01
NU	5.53^{c}±0.01	174.95^{f}±0.02	4.57^{c}±0.01
WI	5.44^{b}±0.01	183.24^{c}±0.02	4.43^{b}±0.02
NI	5.51^{c}±0.01	179.18^{d}±0.02	4.62^{d}±0.02
WO	5.39^{a}±0.01	203.77^{a}±0.03	4.45^{b}±0.01
NO	5.54^{c}±0.01	202.83^{b}±0.02	4.86^{e}±0.01

Values are means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript are significantly different ($p<0.05$). WU-whole tomatoes from Ubani, NU-nkuwa tomatoes from Ubani, WI-whole tomatoes from Isigate, NI-nkuwa tomatoes from Isigate, WO- whole tomatoes from Orie-ugba and NO- nkuwa tomatoes from Orie-ugba.

Color intensity

Just like in TTA, color intensity of whole and *nkuwa* tomato samples from Ubani market (178.68 and 174.95) was significantly ($p<0.05$) lower than those of Isigate (183.24 and 179.18) and Orie-ugba (203.77 and 202.83). These variations are clear indications of influence of distance on color intensity. Depending on the stage of maturity, some degree of ripening and microbial contaminations may have taken place during the transportation periods that must have increased the colour intensity. During ripening, lycopene is synthesized **(Zeb and Mehmood, 2004)**. Also, increase in tannin content with distance (Table 2) may have contributed to colour changes too **(Ayoade *et al*., 2015)**. Significant ($p<0.05$) higher color intensity of all the whole tomato examples than their *nkuwa* counterparts regardless of market locations could be attributed to induced oxidation due to handling damages. From this, it could be inferred that tomato color increase is favoured by aerobic (*nkuwa* tomatoes) enzymatic oxidation and author deterioration than anaerobic condition (whole tomatoes). These could be visualized by deeper red color of samples (Plates 2, 4 and 6) than those of Plates 1, 3 and 5. Color is an index of acceptability as the eyes eat first before acceptance or rejection.

pH

The pH of whole and *nkuwa* tomato samples from Ubani (4.18 and 4.57) was significantly ($p<0.05$) lower than those of Isigate (4.43 and 4.62) and Orie-ugba (4.45 and 4.86). This implied that acidity of whole and *nkuwa* tomatoes decreased with distance from the source of bulk purchase. May be due to more bacterial degradation of acidic tissues of tomatoes **(Mamta and Shashi, 2017)** and therefore may be more susceptible to microbial spoilage. This could be justified by significantly ($p<0.05$) higher pH of both whole and *nkuwa* tomato samples from Isigate than those of Orie-ugba. The pH values obtained in this study were lower than 4.90-5.40 obtained by **Agbabiaka *et al*. (2015)** from three popular markets in Ilorin Kwara State Nigeria. The higher values could be attributed to variety and distance which may have encouraged more microbial contaminations and metabolic products that may have neutralized the tomato fruit **(ICMSF, 2005; Bartz *et al*., 2009)**. The pH decides the extent of spoilage and acceptability. The lower the pH, the more it prevents spoilage and the lower the acceptability and vice versa.

3.2 Phytochemical properties

The results are shown in Table 2.

Tannin

Tannin content of whole tomato sample from Ubani market (0.86mg/100g) was significantly (0<0.05) lower than 0.94mg/100g from Isigate but higher than 0.78mg/100g from Orie-ugba. The disparity could be as a result of differential severity in the handling of the tomatoes which may have resulted in the increased tannin content of tomatoes from Isigate than that of Orie-ugba market. Again, there may be increased microbial activities in the tomato samples from Orie-ugba and some levels of fermentation which may have hydrolyzed the tannin content due to more handling damages and resident time. Therefore, distance and the types of reactions may have been the major causes. In case of *nkuwa* tomatoes, the tannin content of tomatoes from Ubani market (1.09 mg/100g) was significantly ($p<0.05$) lower than those of Isigate (1.15 mg/100g) and Orie-ugba (1.12 mg/100g). The variations could be explained by the above reasons. Tannin is responsible for astringent taste and discolouration **(Ayoade *et al*., 2015)** and may likely affect the acceptability of *nkuwa* tomatoes more than the whole.

Flavonoid

The flavonoid content of the whole (36.77 mg/100g) and *nkuwa* (33.68 mg/100g) tomato samples from Ubani market were significantly ($p<0.05$) higher than those of Isigate (36.66 and 33.57 mg/100g) and Orie-ugba (36.61 and 33.46 mg/100g). Increase microbial activities may be the major cause. Therefore, distance and levels of handling damages decreased the flavonoid content of the tomato samples as evident in the significant ($p<0.05$) higher values of those from Isigate than Orie-ugba markets. Flavonoids are antioxidants that protect consumers against some cancers and cardiac diseases **(Edward, 2016)**.

Phenol

Phenolic content of whole tomato samples decreased significantly ($p<0.05$) with distance from Ubani market (1.39 mg/100g). The values from Isigate and Orie-ugba had no statistical difference (1.38 mg/100g) which may mean that the distance between Isigate and Orie-ugba markets had no significant ($p>0/05$) effect on the phenolic content unlike from Ubani. This may be as a result of shorter distance and the associated handling damages. Phenolic content of *nkuwa* tomato samples from Ubani market (1.44 mg/100g) had no significant ($p>0.05$) variation with that from Isigate but differed significantly ($p<0.05$) with that from Orie-ugba (1.43 mg/100g). Probably, the distance between Ubani and Isigate had no impact unless as from Orie-ugba.

Table 2 Phytochemical content of whole and *nkuwa* tomato samples (mg/100g)

Sample	Tannin	Flavonoid	Phenol	Lycopene	Oxalate
WU	0.86^{b}±0.02	36.77^{f}±0.02	1.39^{ab}±0.01	14.37^{c}±0.02	1.53^{b}±0.01
NU	1.09^{d}±0.01	33.68^{c}±0.02	1.44^{c}±0.01	13.96^{b}±0.02	1.44^{a}±0.01
WI	0.94^{c}±0.01	36.66^{e}±0.02	1.38^{a}±0.02	14.34^{c}±0.02	1.52^{b}±0.02
NI	1.15^{e}±0.01	33.57^{b}±0.01	1.44^{c}±0.02	13.87^{a}±0.01	1.45^{a}±0.02
WO	0.78^{a}±0.01	36.61^{d}±0.01	1.38^{a}±0.01	14.33^{c}±0.02	1.51^{b}±0.01
NO	1.12^{de}±0.01	33.46^{a}±0.01	1.43^{bc}±0.01	13.85^{a}±0.01	1.43^{a}±0.02

Values are means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript are significantly different ($p<0.05$). WU-whole tomatoes from Ubani, NU-nkuwa tomatoes from Ubani, WI-whole tomatoes from Isigate, NI-nkuwa tomatoes from Isigate, WO- whole tomatoes from Orie-ugba and NO-nkuwa tomatoes from Orie-ugba

Lycopene

Lycopene is a vital antioxidant that helps in the fighting cancerous cell formation and other kinds of health complications and diseases. Lycopene content of whole tomato samples decreased without significant ($p>0.05$) variation with distance as evident in slightly higher lycopene content of that of Ubani (14.37 mg/100g) than Isigate (14.34 mg/100g) and Orie-ugba (14.33 mg/100g). Therefore, handling damages due to distance and microbial activities do not have any reasonable impact on lycopene content of whole tomato samples. Similar decreased was also observed in all the *nkuwa* tomato samples, except that the value from Ubani (13.96 mg/100g) was significantly ($P<0.05$) difference from those of Isigate (13.89 mg/100g) and Orie-ugba (13.85 mg/100g) which do not differ significantly ($P>0.05$). The variation could probably be due to variety and extent of damage due to distance while the similarity could be due to reduced microbial activities as a result of their proximity which never had any appreciable effect.

Oxalate

Though there was no significant ($p>0.05$) oxalate decrease in all the whole tomato samples from all the three market locations, but that from Ubani market (1.53 mg/100g) was slightly higher than those from Isigate (1.52 mg/100g) and Orie-ugba (1.51 mg/100g). Oxalate content of whole tomato samples therefore decreased with distance which is a welcome development as higher levels interfere with protein digestion (Ijeh *et al*., 2010). Same reason as in the case of lycopene can explain this. There were also no significant ($p>0.05$) oxalate variations in *nkuwa* tomatoes between all the three market locations, but there was slight increase in Isigate (1.52 mg/100g) and decrease in in Orie-ugba (1.43 mg/100g) from Ubani (1.44 mg/100g). The decrease could be due to cumulative microbial, enzyme and handling damages due to distance and that within Orie-ugba market by the retailers.

Microbial load

Results are shown in Table 3.

Bacteria load (BL)

Bacterial load of whole tomato samples significantly ($p<0.05$) increased with distance from Ubani market (8.02 cfu/mlx10^5) through Isigate (10.01 cfu/mlx10^5) to Orie-ugba (10.53 cfu/mlx10^5). This increase could be due to pH increase (4.18-4.45) with location (Table 1) as high pH (4.5) favours bacteria growth (Mamta and Shashi, 2017). Conversely, the BL of *nkuwa* tomato samples decreased significantly ($p<0.05$) from Ubani (18.04 x 10^6 cfu/ml) through Isigate (11.02 x 10^6 cfu/ml) to Orie-ugba (17.01 x 10^6 cfu/ml). The decrease at Isigate could be due to nutrient depiction and resulted in death of same bacteria while the increase from Isigate to Orie-ugba could be due to recontamination from water used in washing, over crowdedness and dirty environment compared to Isigate. The BL recorded in the three market locations was higher than 4.00 x 10^6 - 7.50 x 10^6 cfu/ml reported by Agbabiaka *et al.* (2015) from three popular markets in Ilorin, Kwara State, Nigeria. Distance, variety, environmental cleanliness, contamination by the traders and consumers and extent of damage may be the cause of variation.

Fungi load (FL)

Fungi load of whole and *nkuwa* tomato samples respectively increased significantly ($p<0.05$) with distance from Ubani (10.03 and 19.54 cfu/mlx10^5) through Isigate (11.06 and 28.34 cfu/mlx10^5) to Orie-ugba (19.52 and 26.02 cfu/mlx10^5). The increase could be visualized by the whitish deposits on Plates 2, 4 and 6 than Plates 1, 3 and 5. The increment may be due to increased handling activities and microbial contaminations as a function of distance from source. Also, more acidic tissues may have been available for attack by the fungi (Mamta and Shashi, 2017). Therefore, FL depended on the degree of damage resulting from handling activities as a function of distance from the source. Besides, relative humidity of the environment (Onwuka, 2014) may have contributed as fungi are surface growing organisms. They also grow in acidic environment which may have resulted from some level of fermentation. The FL loads in this study were lower than 1.60 x 10^6 - 3.50 x 10^6 cfu/ml reported by Agbabiaka *et al.* (2015) from three popular markets in Ilorin, Kwara State, Nigeria. Distance, variety and extent of damage may be the sources of variations.

Table 3 Microbial load of whole and *nkuwa* tomato samples (cfu/mlx10^5)

Samples	Bacterial load	Fungi load
WU	8.02^{a}±0.01	10.03^{a}±0.01
NU	18.04^{f}±0.01	19.54^{c}±0.01
WI	10.01^{b}±0.01	11.06^{b}±0.01
NI	11.02^{d}±0.02	28.34^{e}±0.01
WO	10.53^{c}±0.04	19.52^{c}±0.01
NO	17.01^{e}±0.01	26.02^{d}±0.01

Values are means of triplicate determinations ± standard deviation. Mean values in the same column with different superscript are significantly different ($p<0.05$). WU-whole tomatoes from Ubani, NU-nkuwa tomatoes from Ubani, WI-whole tomatoes from Isigate, NI-nkuwa tomatoes from Isigate, WO- whole tomatoes from Orie-ugba and NO- nkuwa tomatoes from Orie-ugba

4. Conclusion

This study revealed that physicochemical and phytochemical properties as well as microbial loads of whole and broken (*nkuwa*) tomatoes were affected (mostly on the *nkuwa*) by handling damages orchestrated by long transportation distance from the source of bulk purchase. Their color, pH, tannin, bacterial and fungal loads were increased while flavonoid, phenol, lycopene and oxalate decreased. Therefore, tomatoes from Ubani market are the best for human consumption followed by that from Isigate and Orie-ugba. Whole tomatoes should therefore not be transported far away from the place of bulk purchase and must be consumed within two to three days.

Though the microbial loads were within the safe limit, they could be reduced with improved handling processes.
This study will guide the farmers and marketers of tomatoes on how best to handle tomatoes to minimize microbial contaminations and wastes so as to protect life. The general public especially the food vendors should also learn from the health risks associated with the consumption of *nkuwa* tomatoes fruits which are agents in food borne bacteria and fungal diseases Government will be guided by this work on who best to formulate food chain policies in transporting perishable fruits and vegetables like tomatoes in Nigeria.

Conflict of Interest

The authors declare no conflict of interest.

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References

1. Agbabiaka, T. O., Saliu, B. K., Sule, I.O., Oyeyiola, G. P. and Odedina, G.F. (2015).Micro-bial deterioration of tomato sold in three popular markets in Ilorin, Kwara State. Nigeria. *Fountain Journal of Natural Applied Sciences*, 4(1): 10-18.
2. Arnao, M. B., Cano, A. and Acosta, M. (2001). The hydrophilic and lipophilic contribution to total antioxidant activity. *Food Chemistry*, 73: 239–244. .
3. AOAC (2010). *Official Methods of Analysis.* 18th Edn., Association of Official Analytical Chemists, Washington D.C., USA.
4. Ayoade, G. W., Aderibigbe, A, D. and Amoo, I. A. (2015). Effects of different processing operations on chemical composition and functional properties of African breadfruit (*Triculia africana*) Seed. *American Journal of Food Science and Nutrition Research* 2(6):180-185.
5. Baiyewu, R. A., Amusa, N. A., Ayoola, O. A. and Babalola. O. O. (2007). Survey of the postharvest diseases and aflatoxin contamination of marketed pawpaw fruit (*Carica papaya* L.) in south western Nigeria. *African Journal of Agricultural Research*. 2(4): 178-181.
6. Baker, S. (2006). *Aspergillusniger* genomics: past, present and into the future. *Medical Mycology*. 44(1): 17-21.
7. Barth, M., Hankinson, T. R., Zhuang, H. and Breidt, F. (2009). Microbiological spoilage offruits and vegetables. Sperber, W. H. and Doyle, M. P. (Editions), *Compendium of the Microbiological Spoilage of Foods and Beverages, Food Microbiology and safety*. Springer Science + Business Media, LLC, pp. 13-183.
8. Bartz, J.A., Sargent, S.A. and Mahovic, M. (2009). Guides to identifying and controlling post harvest tomato disease in Florida. http://www.edis.ifas.ufl.edu/topic_toma _diseases
9. Behravesh, C. B., Blaney, D. and Medus, C. (2006). Multistate outbreak *Salmonella* serotype *Typhimurium* infections associated with consumption of restaurant tomatoes, USA, (2006). Hypothesis generation through case exposures in multiple restaurant clusters. *Epidemiology and Infection.* 140(11): 2053-2061.
10. Bhowmik, D., Kumar, K. P. S., Paswan, S. and Srivastava, S. (2012).Tomato-a natural medicine and its health benefits. *Journal of Pharmacognosy and Phytochemistry,* 1(1): 33-43.
11. De-Sousa, C. (2008). The impact of food manufacturing practices on food borne diseases. *Brazilian Archives of Biology and Technology*. 51(4):815-823.
12. Edward, G. (2016). What is Phytochemicals? Discovering their health benefits. http://www.globalhealingcenter.com/natural-health/whatarephytochemicals/
13. Effiuwevwere, B. J. O. (2000). *Microbial spoilage agents of tropical and assorted fruits and vegetables*. Paragraphics publishing company, Port Harcourt, Nigeria. Pp. 1-39.
14. Eni, A. O., Oluwawemitan, I. A. and Solomon, A. U. (2010). Microbial quality of fruits and vegetables sold in Sango Ota, Nigeria. *African Journal of Food Science*, 4: 291-296.
15. Fadupin, G.T., Osadola, O.T. and Atinmo, T. (2012). Lycopene content of selected tomato based products, fruits and vegetables consumed in South Western Nigeria. *African Journal of Biomedical Research,* 15:187 – 191.
16. Falegan, C. R. and Oluwaniyi, T. T. (2015). Microbial composition, antibiotic sensitivity and proximate composition of popular imported powdered infant milk formulas sold in Ado Ekiti, Nigeria. *International Journal of Micro-Biology, Genetics and Molecular Biology Research*. 1(1): 10-24.
17. FAO/WHO (2004). Fruit and vegetables for health. Report of a joint FAO/WHO Workshop, September 1-3, 2004, Kobe, Japan. http://www.who.int/dietphysicalactivity/publicati-on activity/publications/fruit_vegetables_report.pdf. (Accessed 30/03/2019).
18. Ghosh, A (2009). Identification of microorganisms responsible for spoilage of tomato (*lycopersicum esculentum*) fruit. *Journal of Phytology,* 1 (6): 414-416,
19. Guyader, F. S. and Atmar, R. L. (2008). Binding and inactivation of viruses on and in food, with a focus on the role of matrix. In: Koopmans, M. P. G., Clive, D. O. and Bosch, A. Editors. *Foodborne viruses: Progress and challenges.* Washington DC: ASM press; pp. 189-208.
20. ICMSF (2005). Microorganisms in foods In: *Microbial ecology of food commodities*. Kluwer Academic/ Plenum Publishers, New York, USA. pp 23-56
21. Ijeh, C.E. Ejike, O.M. Nkwonta, O.M. and Njoku, B.C. (2010). Effect of traditional processing techniques on the nutritional and phytochemical composition of African breadfruit (*Treculia africana*) seeds. *Journal of Applied Sci. Environmental Management*, 14(4):169-173,.
22. Mamta, S and Shashi, B (2017). Food processing, food spoilage and their prevention (An overview). *Inter. Journal Life Science Scientific Research,* 3 (1):753-759.
23. Muhammad, S., Shehu, K. and Amusa, N. A. (2004). Survey of the market diseases and aflatoxin contamination of tomato (*Solanum lycopersicum* MILL) fruits in Sokoto North Western Nigeria. *Nutrition and Food Science*. 34:72-76.
24. Odabasoglu, F., Asian, A., Cakir, A. and Suleyman, H. (2004). Comparison of antioxidant activity and phenolic content of three lichen species. *Phytotherapy Research*, 18(11): 938-941.
25. Ogundipe, F., Bamidele, A., Adebayo-Oyetoro, A., Ogundipe, O. and Tajudeen, O. (2012). Incidence of bacteria with potential public health implications in raw *Lycopersicon esculentum* (Tomato) sold in Lagos State, Nigeria. *Nigerian Food Journal.* 30(2): 106-113.
26. Okwu, D. E. and Omodamiro, O. D. (2005). Effects of hexane extracts and phytochemical content of *xylopia aethiopica* and *Ocimum gratissiumum* on the Uterus of guinea pig. *Bio-research* 3, 30-37.
27. Okwunodulu, I.N., Iwe, M.O. and Akobundu, E.N.T. (2015). Optimization of tropical storage effects on coagulation time and Appearance of un-stabilized micronutrient fortified pre-digested soymilk for complementary feeding. *Journal of Sustainable Agriculture and environment*, 16 (2):363-379.
28. Olutiola, P. O., Famurewa, O. and Sonntag, H. G. (2000). *An introduction to microbiology. A practical approach.* Tertiary Textbook Series., Nigeria.
29. Omolaran, B. B., Habib, U., Odunayo, O. J., Opeyemi, A. S., Alafe, A. H. and Temilade, O. A. (2016). Microorganisms causing post-harvest tomato (*Solanum lycopersicum* L.) fruit decay in Nigeria. *Journal of Entomology and Zoology Studies.* 4(1): 374-377.
30. Onuorah, S. and Orji, M.U. (2015). Fungi associated with the spoilage of post-harvest tomato fruits sold in major markets in

Awka, Nigeria. *Universal Journal of Microbiology Research*. 3(2): 11-16.

31. Onwuka, G.I. (2014). *Handbook of Food Science and Technology.* First Edition. Naphtali Publishers, Lagos, Nigeria. Pp. 279-282.
32. Oranusi, S. U., Oguoma, O. I. and Agusi, E. (2013). Microbiological quality assessment of foods sold in students' cafeterias. *Global Research Journal of Microbiology*, 3(1): 1-7.
33. Seema, R. (2015). Food spoilage: microorganisms and their prevention. *Asian Journal of Plant Science and Research*, 5(4): 47-56.
34. Valadez, A. M. Schneider, K. R.and Danyluk, M. D. (2012) "Outbreaks of food borne disease associated with tomatoes," Tech. Rep. EDIS, 2012(6).
35. WHO, (2007). Food safety and food borne illnesses. Fact sheet no. 237. http://www.who.-int/mediacentre/factsheets/fs237/en/. Accessed on 9/10/2019.
36. Wogu, M. D. and Ofuase, D. (2014). Microorganisms responsible for the spoilage of tomato fruits, *Lycopersicum esculentum,* sold in markets in Benin City, Southern Nigeria. *Scholar's Academic Journal of Bioscience.* 2(7): 459-466.
37. Zeb, A. and Mehmood, S. (2004). Carotenoids contents from various sources and their potential health applications. *Pakistan Journal of Nutrition,* 3(3): 199-204.