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MICROBIAL ANALYSES AND PROXIMATE COMPOSITION OF TOMATO (*Lycopersicum solanum*) FRUITS CULTIVATED ON BIOREMEDIATED SOIL

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ABSTRACT
In this study, some tomato (*Lycopersicum solanum*) fruits were harvested from bioremediated soil while some were bought from the market and agricultural farm. The microbial quality of the tomato fruits obtained from bioremediated soil was analyzed and compared using standard microbiological methods. The proximate composition, mineral and vitamin contents of the tomato fruits were also analyzed using standard analytical techniques. Results obtained from the microbial analyses revealed that tomato fruits from the market recorded the highest fungal loads when compared to tomatoes from other sources. Seven bacterial species isolated from the tomato fruits were *Streptococcus* sp., *Bacillus* sp., *Enterobacter* sp., *Shigella* sp., *Klebsiella* sp., *Staphylococus aureus* and *Leuconostoc* sp. while two fungal species isolated were *Aspergillus niger* and *Aspergillus flavus*. The proximate composition of the tomato fruits revealed no significant difference ($P < 0.05$) in the fibre and ash contents of tomato fruits obtained from the market and bioremediated soil. Tomato fruits from bioremediated soil had significantly higher ($P < 0.05$) carbohydrate content when compared to the tomato fruits from other sources. The mineral composition of the tomato fruits obtained from bioremediated soil had the highest contents of sodium, potassium and phosphorus when compared with tomato fruits from other sources. There was no significant difference ($P < 0.05$) in the vitamin C content of all the tomato fruits that were analyzed. Conclusively, significant improvement in the nutrient availability of tomato fruits obtained from bioremediated soil observed in this study signifies that the concentration of organic manure improved the nutrient quality of the soil which in turns increased the nutrient contents of the tomato fruit cultivated on bioremediated soil.

Keywords: Tomato fruits; bioremediated soils; microbial analyses; proximate composition; bacteria; fungi.

INTRODUCTION

Tomato (*Lycopersicum solanum*) is a popular fruit and an important nutritional and medicinal commodity recognized all over the world. In human diet, it is an important source of micronutrients such as ascorbic acid, vitamin A, minerals (notably potassium), antioxidants, carboxylic acids, and carotenoids (in particular lycopene and phenolic compounds) (Caputo *et al.*, 2004; Hernandez-Suarez *et al.*, 2007; Vallverdú-Queralt *et al.*, 2011). Tomato consumption reduces the risks of cardiovascular disease and certain types of cancer, such as prostate, lung, and stomach (Canene-Adams *et al.*, 2005). Despite the health benefits, contamination of fresh produce is of special concern because such produce is likely to be consumed raw, without any type of microbiologically lethal processing, thus posing a potential health risk (Badosa *et al.*, 2008).

Tomato is also popular because it is a most rewarding crop for home garden since it grows well practically everywhere, and it provides high nutrition in many forms such as raw in salads; cooked in soups, sauces, pickled and in other forms. The quality of tomato for fresh market, in organic or conventional production system, is determined by appearance, firmness and flavour; although the quality of the processed tomato is determined essentially by soluble solids, colour, pH and firmness (Clemente and Boiteux, 2012). Bioremediation refers to the removal, destruction, or transformation of contaminants to less harmful substances through the activities of biological agents. Its effectiveness in removing numerous pollutants from many contaminated sites have been well documented (Rimmer *et al*., 2006; Nie *et al*., 2009; Li *et al*., 2013). Generally, bioremediation technologies can be classified as *in situ* or *ex situ*. *In situ* bioremediation involves treating the contaminated material at the site while *ex situ* involves the removal of the contaminated material to be treated elsewhere (Gavrilescu 2010). The discharge of effluents arising from industries has caused severe pollution of both the surface water and groundwater and also contaminated soils and crops in agricultural land (Palanisamy *et al*., 2008). Plant uptake is one of the major pathways by which soils contaminants enter the food chain. The food-chain plants might absorb enough amounts of chemical constituents of these contaminants to become a potential health hazard to consumers (Rasheed and Awadallah 1998).

In this study, tomato fruits were harvested from previously hydrocarbon polluted soil which had been bioremediated with piggery manure as biostimulant. These tomato fruits were analyzed microbiologically to determine the microbial loads and types of microbes that are present on the tomato fruits while proximate composition and nutrients were also analyzed to ensure the nutrient quality of the fruits.

MATERIALS AND METHODS

Sample Collections

Tomato fruits were collected in units of three (3) and each fruit was individually analyzed. Samples were obtained from three (3) different locations as follows: Bioremediated soil, Federal University of Technology, Akure farm (agricultural farm) and Oba Market in Akure, Nigeria. All samples were taken to the laboratory in sterile plastic bags and kept in the refrigeration for further analyses.

Sterilization of Materials Used

Glass wares were washed with detergents, rinsed with tap water and oven dried at 160°C for 1 hour. Forceps and inoculating loops were flamed to red-hot with the aid of a Bunsen burner and then dipped in 70% ethanol. Incubators, inoculating and growth chambers were fumigated with 40% formaldehyde. Work benches were disinfected by cotton wool moistened with 70% ethanol (Fawole and Oso, 2006).

Preparation of Culture Media

Nutrient agar, Eosin Methylene Blue, Mannitol Salt agar, *Salmonella Shigella* Agar and Potato Dextrose agar were weighed according to the manufacturer's specification. Agar was weighed and introduced into clean conical flask and distilled water added. The flasks were plugged with foiled paper and cotton wool to prevent leakage, swirled gently and homogenized on a hot plate. The culture media were sterilized by autoclaving at 121°C for 15 minutes. After sterilization, the sterilized media were allowed to cool to about 45°C and poured into Petri dishes aseptically (Fawole and Oso 2009).

Isolation of Microorganisms from Tomato Fruits

Tomato samples were homogenized using mortar and pestle, 1mL of the supernatant of each sample was poured into sterile test tubes containing 9 mL distilled water as stock. One

millimeter (1mL from each stock solution was further serially diluted to 10^6 solution, 0.5mL of 10^3 and 10^5 of each sample was poured into Petri dishes containing the media. Plates were inverted and placed in the incubator for 18-24 hours at 37°C for bacterial growth while fungal sample was kept at room temperature (25 ± 2°C) between 3 and 7 days.

Sub-culturing Isolates

Each distinct colony from the media was sub-cultured using sterile inoculating loop on Nutrient Agar (NA) using streak technique for bacteria and Potato Dextrose agar (PDA) for fungi. This inoculated medium was incubated at 37°C for 18-24 hours for bacteria and (25 ± 2°C) for 3-7 days for fungi according to the method described by (Cheesbrough, 2006).

Identification of Microorganisms

The plates were examined for growth and the morphological appearance of the microorganisms after the incubation. Microorganisms were identified by carrying out morphological and biochemical tests according to the method described by Cheesbrough (2014).

Morphological and Biochemical Tests

Gram Staining

A heat fixed smear of 18-24 hours old culture was prepared on a clean microscope slide. The smear was stained with crystal violet for 30-60 seconds; after which the stain was rinsed off with distilled water under a running tap. Lugol's iodine, a mordant was added to intensify stain for 60 seconds and was rinsed off with distilled water. 95% ethanol was added to the slides as a decolourizer for 10-15 seconds and rinsed off under a running tap. Safranin, a counter stain was added to the smear for 30 seconds, rinsed off with distilled water. The slides were allowed to air dry and then observed under x100 oil immersion objective binocular microscope (Cheesbrough 2014).

Motility Test

Culture broth was prepared for the motility test. The inoculum was introduced into sterilized broth and incubated at 37°C for 24 hours. Inoculating loop was used to transfer two loopfuls of the culture broth into a cavity slide and covered with cover slip. The cavity slide was inverted quickly in order for the drop not to run off to one side and it was examined under ×40 objective lens (Fawole and Oso, 2007).

Spore Staining Test

This test was carried out according to the method of Schoeffer-Fulton (Fawole and Oso, 2012). A smear of the isolate was stained with 5% malachite green and heated over a beaker of boiling water for ten minutes. The stain was washed off with distilled water, 0.5% aqueous safranin was used to counter stain for 15 minutes. This was washed off with distilled water and allowed to dry, immersion oil was added before viewing with microscope. Bacterial spores stained green while vegetative cells stained red on microscopic examination.

Biochemical Tests

Oxidase Test

The oxidase reagent was prepared by dissolving 0.1 g of tetramethyl-p-phenylenediamine in 10 mL of sterile distilled water. Clean Whatman filter paper was placed in a Petri dish and three drops of the freshly prepared oxidase reagent added to it. A freshly prepared culture isolate was smeared across the impregnated paper with a platinum loop. A positive reaction was indicated by the appearance of a dark purple colour on the paper within 10 seconds (Cheesbrough, 2006).

Catalase Test

A 3 mL of hydrogen peroxide (3%) was poured into a test-tube. A sterile glass rod was used to remove colonies of the test organism and immersed in the hydrogen peroxide solution. Bubble formation indicated a positive catalase test (Cheesbrough, 2006).

Coagulase Test

A drop of normal saline was placed on a slide and emulsified with a colony of the test organism to make a thick suspension. A drop of

plasma was added to the thick suspension and mixed gently; clumping, signified a positive coagulase test (Cheesbrough, 2014).

Indole Production Test

This was performed by growing the isolates in 10 mL sterile Tryptone water (Oxoid, Basingstoke, UK) for 24 hours at 37°C. Kovacs' reagent (0.5 mL) was then added to the culture using a pipette. The test tube was shaken and examined after one minute. The presence of Indole was detected by the appearance of a red layer in the medium while its absence was denoted by a yellow layer (Cheesbrough, 2006).

Citrate Test

Two sets of slants of Simmons citrate agar were prepared in Bijou bottles, with the aid of sterile straight wire. Normal saline suspension of the test organisms were streaked on the slants and were incubated at 37°C for 48 hours. A bright blue colour on the agar slants indicated positive result (Cheesbrough, 2006).

Sugar Fermentation Test

Each of these sugars (glucose, fructose, lactose, sucrose and mannitol) was prepared in a sterile broth. Phenol red indicator was added (2 drops) and 10mL of the broth was dispersed into test tubes and plugged with cotton wool and autoclaved at 121 °C for 15 minutes. Each isolate was inoculated into each tube and incubated for 4-5 days at 37 °C. Acid production was indicated by a color change while gas production was indicated by the presence of air space in the Durham's tube (Fawole and Oso, 2007).

Urease Test

A little of the culture of the test bacteria was streaked over the surface of the agar slant of urease test medium with phenol red as indicator and incubated at 37°C for 7 days. A control of the basal medium containing no added urea was equally inoculated. A colour change of the medium from yellow to pink or red was an indication of a positive result and no colour change indicate a negative result (Fawole and Oso, 2012).

Identification of Fungal Isolates

This was carried out through morphological appearance and staining. Using a pasture pipette, two drop of Cotton-Blue-in-Lactophenol was placed on a clean slide. The mycelium of the isolate was collected aseptically using sterile inoculating needle and teased out on the slide carefully. A cover slip was rightly placed on it and then viewed under the microscope (×40 objective lens) according to the method described by (Fawole and Oso, 2012).

Proximate Analyses

Moisture Content

Dry matter was determined by oven drying at 105°C to a constant weight. A 5g of each sample was weighed into pre-weighed dry dishes and kept in oven adjusted at 105°C. After 6 hours, the samples were withdrawn, cool in a desiccator and reweighed.

Moisture content of each sample was calculated as follows:

$$\%\ \text{Moisture} = \frac{Loss\ in\ weight\ due\ to\ drying \times 100}{Original\ weight\ of\ sample} \quad (1)$$

$$\%\ \text{Moisture} = \frac{W_2 - W_3 \times 100}{W_2 - W_1} \quad (2)$$

Where

W_1 = Initial weight of crucible

W_2 = Weight of crucible + sample before drying

W_3 = Weight of crucible + sample after drying

Crude Protein Content (Micro-Kjeldahl method)

Sample weighing 5g was mixed with 15g of potassium sulphate (K_2SO_4), 0.7g mercuric oxide, copper sulphate ($CUSO_4$) as catalyst and digested in a long necked Kjeldhal bottles with 40 mL concentrated sulphuric acid for approximately 2 hours. Distilled water (200 mL) and 25 mL sodium thiosulphate solution (80g/l) were added. The content of the digestive flask was mixed and boiled until at least 150 mL was distilled into the receiver. Five (5) drops of methyl red indicator solution (0.5g/100ml ethanol) was added to the mixture before

titration with 0.1M sodium hydroxide. The percentage nitrogen obtained was multiplied by a conversion factor (6.25) to get the crude protein.

$$\% \text{ Nitrogen} = \frac{Va - Vb \times A \times 100}{Wt} \quad (3)$$

Va = Volume of acid required to titrate sample
Vb = Volume of acid required to titrate blank
A = Acid normality
Wt = Weight of sample

$$\text{Crude Protein} = \%\text{Nitrogen content} \times \text{Conversion factor } (6.25) \quad (4)$$

Mineral Ash Content

Mineral ash content was determined by heating 5g of each grinded tomato sample in a clean dry crucible. This was charred over a Bunsen flame in a fume cupboard to destroy most of the organic matter. The heated tomato samples were further heated in a muffle furnace at about 500°C for about 3 hours until white ash remained. Heated tomato samples were allowed to cool in a desiccator and reweighed. Ash was calculated as follows:

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \quad (5)$$

$$\text{Ash (dry basis)} = \frac{W3 - W1}{W2 - W1} \times 100 \quad (6)$$

Where:
W1 = Initial weight of empty crucible
W2 = Weight of crucible + sample before Charring
W3 = Weight of crucible + white ash

Crude Fat

This was done using Soxhlet method. Five grammes (5g) of each tomato sample was weighed into a small porcelain bowl and heated in an oven at 105°C for one hour. After cooling, the dry tomato samples were transferred into Soxhlet thimble. The samples in the thimble were then covered with glass wool and placed into Soxhlet apparatus fat extraction units. Dry and clean fat extraction flask (pre-weighed) was placed into the extraction unit together with about 300 mL of petroleum ether (boiling point 40 – 60°C) and was allowed to reflux for about 6 hours. Extraction was carried out on each of the sample. Finally, petroleum ether was evaporated off and the flask dried in an oven at 105°C for about 1 hour and then transferred into a desiccator to cool. The weight increase of the flask was estimated as corresponding to the fat content. Fat was calculated as follows:

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100 \quad (7)$$

Crude Fibre Content

Crude fibre content was determined after boiling 5g defatted sample in refluxing Sulphuric acid and sodium hydroxide. The defatted 5g sample was treated with light petroleum hydroxide (about 0.1313 N 200 mL NaOH). Sulphuric acid was used to disperse the sample. The mixture was heated to boiling point within one minute (in a Liebig reflux condenser). The whole insoluble material was transferred to the filter paper by means of dilute hydrochloric acid. The final residue was filtered through with the aid of a pre-weighed filter paper used to line a Buckner funnel connected to a vacuum pump. The insoluble matter transferred to the weighed filter paper was dried at 100°C to a constant weight. The filter paper content was incinerated to ash. The weight of the ash was subtracted from the increased weight of the paper and insoluble material. The difference in weight was reported as crude fibre i.e.

$$\% \text{ Crude fibre} = \text{the loss in weight incineration} \times 100 \quad (8)$$

Carbohydrate Content

Available carbohydrate was determined by subtracting the total values of crude protein, moisture content, fat, crude fibre, and ash content of the tomato samples from 100.

$$\text{Carbohydrate} = 100 - (\% \text{ protein} + \% \text{ moisture content} + \% \text{ fat} + \% \text{ fibre} + \% \text{ ash}) \quad (9)$$

Mineral Content

Five grams (5g) of each tomato sample was heated gently over a Bunsen burner flame until most of the organic matter was destroyed. This was further heated strongly in a muffle furnace

for several hours until white-grey ash is obtained. The ash material was allowed to cool. About 20 mL of distilled water and 10 mL of the dilute hydrochloric acid was added to the ashes material. The digest samples were analyzed for heavy metals, and iron (Fe) using atomic absorption spectrophotometer. Bulk Scientific Model VGB 210 System (2008) edition 6.

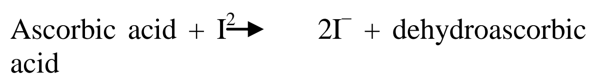
Vitamin C

100g of each of the tomato samples was blended in a food processor with 50 mL of distilled water. After blending, the pulp was strained through cheese cloth, washed with few portion of distilled water, and the extracted solution was made up to 100 mL in volumetric flask.

Titration

20 mL of the aliquot solution of the sample solution was pipetted into 250 mL conical flask, 150 mL of distilled water and 1 mL of starch indicator solution were added. The sample was titrated with 0.005 mol/L iodine solution. The end point of the titration was identified as the first permanent trace of a dark blue-black colour due to the starch iodine complex. The titration was repeated with further aliquots of the sample solution until concordant result is obtained (titres agreeing within 0.1 ml). Average volume of iodine solution used from concordant titre was calculated, moles of iodine reaction were calculated, and moles of ascorbic acid reaction were calculated i.e.

Ascorbic acid + $I^2 \rightarrow$ $2I^-$ + dehydroascorbic acid



Concentration of ascorbic I mol/L of ascorbic in the solution obtained from the sample was calculated.

Vitamin A (µg/100g)

Two grams (2g) of each sample was weighed into a flat bottom flask, 10 mL of distilled water was added and shaken carefully to form a paste. 25 mL of alcoholic KOH solution was added and a reflux condenser attached. The mixture was heated in boiling water bath for 1 hour with frequent shaking. The mixture was allowed to cool and 30 mL of water was added. The hydrolysate obtained was transferred into separating funnel. This was extracted three times with 250 mL quantities of chloroform. 2g anhydrous Na_2SO_4 was added to extract any trace of water. The mixture was filtered into 100 mL volumetric flask and made up to mark with chloroform. Standard solution of β-carotene Vitamin A of range 0 - 50µg/ml with chloroform was prepared by dissolving 0.003g of standard β-carotene in 100 mL of chloroform. The above gradients of different standard solution prepared were determined with reference to their absorbance from which average gradient was taken to calculate Vitamin A (β- carotene in µg/100g). Absorbance of sample was measured using Spectrophotometer at a wavelength of 328nm.

$$\text{Vitamin A}\left(\frac{\mu g}{100g}\right) = \text{Absorbance of sample} \times \text{Dilution Factor of weight of sample} \quad (10)$$

Statistical analysis

Data obtained was subjected to single way analysis of variance (ANOVA) while the significant means was separated with Duncan's multiple range test (DMRT) at 5% level of significance using SPSS (version 21).

RESULTS

Total Viable Count Obtained from the Tomato Fruits

The microbial loads of the tomato fruits are shown in Figure 1. The bacterial loads of the tomato fruits from all the sources examined ranged from 7.00 ± 1.00 (Bioremediated soil) to 11.33 ± 0.88 (Agricultural farm) Cfu/g. There is no significant difference (P<0.05) between the bacterial loads of tomato obtained from Oba market and FUTA farm. Tomato fruits obtained from the market had the highest fungal load with a value of 5.33 ± 0.33 Sfu/g.

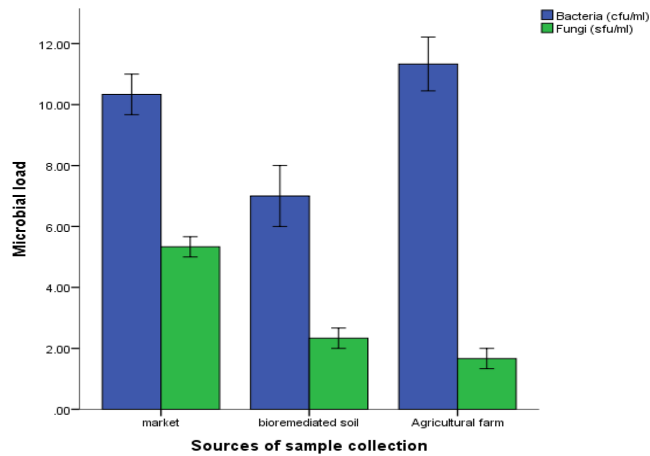


Figure 1: Microbial Load of the Tomato Fruits

Cultural Characterization, Biochemical Test of Bacteria and Fungi Isolated from the Tomato Fruits

Microorganisms (bacteria and fungi) isolated from the tomato fruits collected from the three different sources are shown in Tables 1 and 2. Seven bacterial isolates were identified as *Streptococcus* sp., *Bacillus* sp., *Enterobacter* sp., *Shigella* sp., *Klebsiella* sp., *Staphylococus aureus,* and *Leuconostoc* sp. while two fungal isolates identified were *Aspergillus niger* and *Aspergillus flavus*.

Occurrence of Microorganisms Isolated from the Tomato Fruits

Bacillus sp., *Shigella* sp., *Staphylococcus aureus*, *Streptococcus* sp., *Enterobacter* sp., *and Klebsiella* sp. were isolated from all the tomato fruits collected from the three sample sources, while *Leuconostoc* sp. was only isolated from tomato fruits collected from market and FUTA agricultural farm (Table 3). *Aspergillus* sp. and *Aspergillus flavus* were isolated from all the tomato fruits examined.

Table 1: **Biochemical Characterization**

Tests	IS01	IS02	IS03	IS04	IS05	IS06	IS07
Colonial Shape	Entire Yellowish Opaque	Large flat colonies with irregular edges.	Whitish pink colonies on EMB agar	Whitish pink colonies on SSA agar	Pinkish mucoid colonies on EMB	Whitish tiny colonies	Flat translucent colonies
Gram Reaction	+	+	-	-	-	+	+
Shape	Cocci	Rod	Rod	Rod	Rod	Cocci	Cocci
Motility	-	-	+	-	-	-	-
Spore formation	-	+	-	-	-	-	-
Citrate	-	+	-	-	+	-	+
Urease	-	-	-	-	-	-	+
Catalase	-	+	-	-	-	+	-
Coagulase	+	-	-	-	-	+	-
Oxidase		-	-	-	-	-	+
Methyl red	-	-	-	-	+	-	+
Indole		-	-	-	-	-	-
Glucose	+	+	+	-	-	+	+
Lactose	+	+	+	-	-	+	+
Mannitol	-	+	+	-	-	+	+
H_2S	-	-	-	+	-	-	-
Suspected organisms	*Streptococcus* sp.	*Bacillus* sp.	*Enterobacter* sp.	*Shigella* sp.	*Klebsiella* sp.	*Staphylo coccus aureus*	*Leuconotoc* sp.

Key: + = positive - = negative, EMB agar = Eosin methylene blue agar,
SSA agar = *Salmonella-Shigella* agar

Table 2: Cultural and Morphological Characteristics of Fungi and their Identification

Cultural Characteristics	Morphological Characteristics	Identification
Dark- brown mycelia	Dark-brown conidia, conidiophores are long, globose vesicles that are completely covered with biseriate phialides. Phialides are borne on brown metulae	***Aspergillus niger***
Colonies are olive to lime green with a cream reverse.	Hyphae are septate and hyaline. Conidiophores are coarsely roughened and uncoloured. Vesicles are globose, metulae are covering the entire vesicle in biserate species.	***Aspergillus flavus***

Table 3: Occurrence of Microorganisms Isolated from the Tomato Fruits

Microbial Isolates	**Sources of sample**		
	Market	Bio-remediated soil	Agricultural farm
***Streptococcus* sp.**	+	+	+
***Bacillus* sp.**	+	+	+
***Enterobacter* sp.**	+	+	+
***Shigella* sp.**	+	+	+
***Klebsiella* sp.**	+	+	+
Staphylococcus aureus	+	+	+
***Leuconotoc* sp.**	+	-	+
Aspergillus niger	+	+	+
Aspergillus flavus	+	+	+

Key + = present; - = absent

Proximate Composition of the Tomato Fruits

The proximate composition of the tomato fruits collected from the three different locations are shown in Table 4. The fibre and ash contents of tomato fruits obtained from the Oba market and bioremediated soil showed no significant difference ($p<0.05$). Fat contents for all the tomato fruits analyzed ranged between 0.03% (Bioremediated soil) and 0.08% (Market). Tomato obtained from the Oba market had the highest moisture content with value of 90.28% with significant difference ($p<0.05$) compared with tomato fruits obtained from bioremediated soil and FUTA farm (90.16 ± 0.02 and 80.26 ± 0.01%). Tomato fruits from bioremediated soil were significantly different at $P = 0.05$ in the carbohydrate contents when compared to the tomato fruits from other sources.

Mineral Composition of the Tomato Fruits

The mineral composition of the tomato fruits is shown in Table 5. Potassium had the highest value among the entire minerals assayed for in all the tomato fruits. Tomato fruits of bioremediated soil have the highest content of sodium (18.11 ± 0.01), potassium (423.17 ± 0.03) and phosphorus (40.13 ± 0.01) when compared with tomato fruits from other sources. Iron had the lowest concentration of all the minerals analyzed. Iron concentration ranged from 0.14 ± 0.01 (Agricultural farm) to 0.34 ± 0.02 mg/kg (Market).

Vitamin composition of the tomato fruits

Tomato fruits obtained from FUTA agricultural farm had the highest content of vitamin A with value 0.563 ± 0.03mg/kg which differ significantly ($P>0.05$) from tomato fruits obtained from Oba market and bioremediated soil (50.01 ± 0.02 and 47.89 ± 0.04 mg/kg). No significant difference ($P>0.05$) in the vitamin C contents of all the tomato fruits analyzed as shown in Figure 2.

Table 4: Proximate Composition of Tomato Fruits.

Sources of sample	Proximate composition					
	Fibre	Protein	Fat	Ash	CHO	Moisture
Market (%)	2.21±0.03^{b}	1.12±0.01^{a}	0.08±0.01^{b}	0.08±0.01^{a}	6.24±0.01^{b}	90.28±0.03^{c}
Bioremediated soil (%)	2.11±0.01^{b}	1.22±0.01^{b}	0.03±0.00^{a}	0.06±0.00^{a}	6.72±0.00^{c}	90.16±0.02^{b}
FUTA farm (%)	1.47±0.25^{a}	1.44±0.00^{b}	0.04±0.00^{a}	0.60±0.01^{b}	5.25±0.01^{a}	80.26±0.01^{a}

Data are presented as Mean ± S.E (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P<0.05) **Key :** CHO = Carbohydrates

Table 5: Mineral composition

Sources of sample	Mineral composition					
	Na	K	Ca	Mg	P	Fe
Market	17.12±0.03^{a}	377.22±0.01^{b}	15.24±0.01^{b}	18.22±0.01^{b}	38.27±0.02^{a}	0.34±0.02^{c}
Bio-remediated soil	18.11±0.01^{c}	423.17±0.03^{c}	14.14±0.01^{a}	17.24±0.01^{a}	40.13±0.01^{c}	0.23±0.01^{b}
Agricultural farm	17.25±0.02^{b}	344.21±0.01^{a}	16.22±0.02^{c}	18.46±0.01^{c}	39.22±0.01^{b}	0.14±0.01^{a}

Data are presented as Mean±SE (n=3). Values with the same superscript letter(s) along the same column are not significantly different (P<0.05)

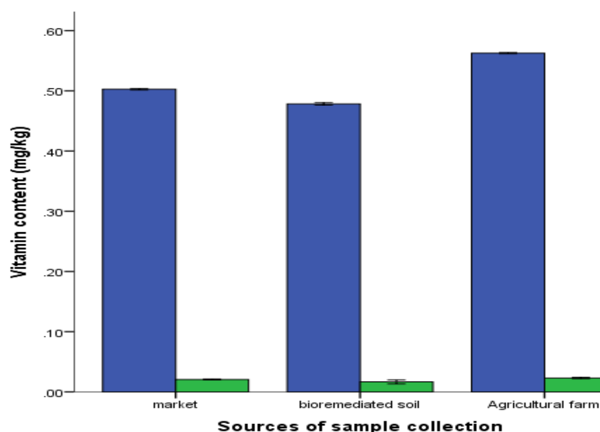


Figure 2: Vitamin A and C Contents of the Tomato Fruits

DISCUSSION

The result of this study indicates that tomato fruits from the market and FUTA farm recorded the highest bacterial loads when compared to the tomato fruits planted on bioremediated soil. Tomato fruits from the market also recorded the highest fungal loads when compared to tomato fruits from other sources. The high microbial loads from the tomato fruits obtained in this study may arise from during harvesting and post-harvest handling. Other factors such as storage, transportation, packaging and distribution (loading and off-loading) at various channels and selling

outlets may be responsible for the significant microbial growth recorded for the tomato fruits obtained from the market. This study is in accordance with the work of Baiyewu *et al*. (2007) who reported that tomato fruits in the market are often displayed in baskets and on benches thereby exposing them to opportunistic microorganisms and further justified by the work of Beuchat (2002) who concluded that the natural protective cover (epidermal layer) of tomato fruits are hindered and contaminated during field cultivation, harvesting, post-harvest handling, storage and distribution.

The probable identity of the microorganisms include; *Streptococcus* sp., *Bacillus* sp., *Enterobacter* sp., *Shigella* sp., *Klebsiella* sp.., *Staphylococcus aureus*, and *Leuconotoc* sp., which is in agreement with the findings of previous researchers who had earlier isolated these microorganisms from tomato fruits (Chinedu and Enya, 2014; Oyemaechi *et al.*, 2014; Bello *et al*., 2016). The identity of fungi isolated, that is, *Aspergillus niger* and *Aspergillus flavus*, is in agreement with the report of Chuku *et al* (2008) and Akinmusire (2011) who reported that *A. flavus* and *A. fumigatus* are the causative organisms of tomato fruits spoilage. The presence of enteric bacteria on the tomato fruits may be due to the exposure of the tomato fruits to fecal contaminated irrigation water and also the organic manure used for the bioremediation process (Amoah *et al,* 2009). These enteric bacteria may be transferred from the manure to the soil and then to the tomato fruits. The presence of *Staphylococcus aureus* may also be through nasal passages of healthy food handlers or through contact with an infected skin (Adams *et al*., 2009). *Bacillus* sp. has been recorded to have its natural habitat in the soil, hence its presence in all the tomato fruits analyzed (Agarwal *et al*., 2000).

The proximate composition revealed that all the tomato fruits examined have high moisture contents. The high moisture contents reported in this study agreed with the findings of Hossain *et al*. (2010), who also reported the moisture content of tomato fruits to range between 88.19% and 90.67%. Udoh *et al.* (2005) reported that the susceptibility of tomato fruits to microbial colonization is due to its high moisture content which favour the growth of spoilage microorganisms. Foods with low moisture contents have long shelf life (Mohammed *et al*., 2017), thus tomato fruits have a short shelf life because of the high moisture content. The fibre content reported is also in accordance with the report of Onifade *et al*., (2013), who reported fibre content of different tomato cultivar within the range of 0.70% and 3.25%. The increase in nutrient content of the tomato fruits from the bioremediated soil may be as a result of the piggery manure added for the bioremediation process, since manure is a natural source of organic matter and nutrients (Awosika *et al*., 2014).

The variation obtained in the nutrient composition of the tomato fruits examined in this study agreed with Mohammed *et al*. (2017) who reported that the proximate compositions such as moisture, acidity, crude fibre, protein, vitamin C and lycopene of tomato fruits differ with cultivars, cultural and post-harvest handling practices.

CONCLUSION

This study revealed that several opportunistic pathogenic microorganisms are associated with tomato fruits and this is of high potential hazard to consumers especially the illiterate majority who are not aware of such risks and can consume tomato fruits even without any proper washing. The result from this research also reveals that tomato fruits obtained from bioremediated soil have high nutritional composition (proximate, vitamins, minerals) as well as the fruits obtained

from other locations, thus they are safe for consumption with the right hygiene practices.

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