Effects of cassava mill effluent (CME) on bacteria diversity of soil and aquatic environments in South-South Nigeria

Abstract

The effects of cassava effluent on the bacteria diversity of Nkissa River in South-south area of Nigeria and the adjoining soil were investigated. Results obtained in soil analysis showed changes in temperature (28.6-32.6 °C), pH (7.2-10.3) and toxicity of cassava (TOC) (24.2±4.13 mg/l). Highest values were obtained near the waste pit while control soil had the least values. Cyanogenic potential was highest near the pit. Total heterotrophic bacteria count ranged from 3.7×10⁶-6.6×10⁷ CFU/g. Phosphate solubilizing bacteria count ranged from 2.2×10⁴-2.9×10⁵ CFU/g. In all cases, highest values were obtained 100 m from the waste pit, followed by the control while the least was in the pit edge. The water analysis showed that dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) were adversely affected by the cassava effluent as values from the upstream were significantly (p=0.05) lower than those from the discharge point (DP) to the downstream areas (DS I and DS II). The metallic ions were not significantly affected. The cyanogenic potentials of the water samples were quite low (1.03-0.42 mg/l). Klebsiella Corynebacterium, Acinetobacter; and Morexallia species which were absent from Upstream (US), were found from the Discharge/Fallout Point (DFP) to the Downstream (DS) samples. Saccaromycetes, Escherichia, Lactobacillus, Bacillus and Micrococcus species were found in all the water samples analyzed. The cassava effluent utilization test showed that Alcaligenes, Xanthomonas, Lactobacillus, Corynebacterium and Micrococcus species are good metabolizers of the effluents indicated. However, Escherichia and Enterobacter species did not utilize the effluent at all. Results indicated adverse effects of the cassava mill effluent (CME) on soil parameters and water qualities which call for regulations on the disposal of CME to avoid environmental degradation.

Keywords: bacteria diversity, cassava effluent, environmental degradation, soil, water, mill effluent, sheep, cyanogenic glucoside, environmental conditions.

Introduction

Cassava is a single species crop, (Manihot esculenta) though with several varieties. It is a dicotyledonous plant belonging to the botanical family Euphorbiaceae. It contains laticifers and produces latex. The cassava plant is said to originate in Northeast Brazil with an additional Centre of origin in Central America, from these Centers, the crop spread to several parts of the world including Africa, Asia and America especially in the tropical zones. There are several varieties and cultures but generally cassava is said to be of two main varieties based on the characteristics and contents of its Cyanogenic glycoside of its root/tubers. These are bitter and sweet; the bitter variety has its Cyanogenic glucoside distributed throughout the tuber and in high concentration while the sweet variety has low Cyanogenic glucoside, mainly in the peel of the tuber. The fresh/pulp of the sweet variety therefore has low Cyanogenic glucoside. However, the growing environmental conditions could influence the Cyanogenic glucoside concentrations of each variety. Cassava is grown in tropical lowland under warm, moist climate with a temperature range of 25-30 °C and rainfall of 100-150cm per year well distributed. It can however, grow under lower rainfall levels too but not doing very well. The best soil fertility as high fertility encourages more vegetative growth than tube formation. Cassava is a perennial plant, usually harvested within 12-18months naturally.

Generally, cassava crop is cultivated for its tubers/roots, but cases of other parts of the plant being put into effective uses abound especially the leaves. Cassava leaves has been used as vegetable for human consumption in a few East African countries like Tanzania, Angola, and Malawi. The root tubers produced over 20-30% of the total harvest has been used in animal feed supplements. In animal feed, the leaves serve as forage material.1 The leaves are harvested and feed to domestic animals like goats, sheep and cattle while the cassava tubers peels are served to pigs as feed supplements. Before utilization of the tuber it is inevitably peeled; about 0.5-2.0% of the tuber is the peel while the edible part is 80-90%.This edible fleshly tuber is composed of 60-70% water, 30-35% carbohydrate, 1-2% protein while fiber, fat and mineral matter make up the remaining. Two important factors that influence the use of cassava tuber are the high content of Cyanogenic glucosides and lack of good storage or keeping quality of the fresh tuber. This implies that the tubers will only be consumed after elaborate processing to reduce the Cyanogenic glucoside content and improve the keeping quality.2 Processing of cassava tubers for human consumption gives four types of products; these include the meal, flour, chips and starch production.1,4 The processing of these cassava tubers result in generation of several types of waste which include not only the peel but the effluent inclusive.
The effluent include the milky colloid pressed out of the fresh tuber paste, the latex, the wash water, etc.

These wastes are automatically discharged into the surrounding environment causing pollution. The above mentioned pollution effects from cassava wastes becomes more pronounced as specific mills are now established to process cassava tuber to obtain garri and starch, the two forms in which the tubers are mainly consumed. In most cassava tuber preparations, the processing mills are established near water bodies or in free land spaces. The discharge of the cassava mill waste results in offensive odour emanating from the biodegraded products of the waste.³ In this case, the cassava mill effluent (CME) wastes affect the soil or water microbiological properties which in turn affect the general productively of the particular ecosystem.¹ Since cassava contains some minerals that affect the soil or water quality, assessment of the impacted habitat therefore involves the factors to obtain an appropriate view of the situation. Having established that human activities for economic, food or industrial objectives impact on the environment; the impacted environment should be assessed in order to determine the premeditative approach for a safer, greener and healthier habitat. Therefore, this study evaluates the effect of cassava mill effluent (CME) on bacteria diversity of soil and aquatic environments in south-south.

Materials and methods

Study Area

The study area was Okwuzi, community of Egbema, River State Nigeria. It is a rainforest area with tropical climate. Egbema has vegetation characterized by tall trees and green grasses. The people are mainly fishermen and farmers with cassava and yam being the main crop grown along with palm trees and vegetables. Nkissa River empties into the Orashi River in Egbema; the river is an all season one. Two large cassava-processing plants were established in 2001 and 2002 on either sides of the river and processes between one and two (1-2) tones of cassava tubers daily.

Collection of samples

Soil samples were collected using shiprek soil auger disinfected with cotton wool soaked in 70% ethanol at 0-15 cm depth. Four sampling areas of the mill were chosen, the areas sampled were the pit edge, 5m, 10m and 100m away while the sample from 250 m away have the highest counts in all the soil samples analyzed (Table 3). Soil samples were collected at each sampling point and pooled together to form the sample for that particular point. Sampling was done ten (10) times at two weeks intervals for microbiological analysis. Nutrient agar, Mineral agar and MacConkey agar was used.

The physicochemical analysis

The temperature was determined by the use of mercury in bulb thermometer as described. The pH was determined using Jenway Hanna 1910 multipurpose tester. The dissolved oxygen (DO) was measured with the (DO, meter Jenway, model 9071, USA). The biological oxygen demand (BOD) was determined using titrimetric method as described. The total dissolved solids (TDS) and total suspended solids (TSS) were determined by the method of HACH. Total carbon content of the samples was determined according to the method of Nwaugo et al.,³³ Sampling of the Nkissa River was done at two (1-2) tones of cassava tubers daily.

Microbial analysis

Determination of bacteria load

Each of the soil samples was serially diluted on a ten-fold dilution. Exactly 0.1 ml from 10⁻³ dilution factor was transferred to various media, tripone soy agar, MacConkey agar, Tributyrin agar, mineral salt agar and phosphate solubilizing medium for determination of total heterotrophic count, total coliform count, nitrifying bacteria and phosphate solubilizing bacteria respectively, using spread plate technique as described. The plates were incubated at 37 °C for 28 hours. Discrete colonies were counted and determined as cfu/g. The same procedure was adopted for the water samples and reported as cfu/ml.

Identification of isolates

The discrete colonies were sub-cultured on fresh nutrient agar medium and incubated at 37 °C for 24 hours to obtain pure cultures. The pure cultures obtained were characterized using microscopy, biochemical and sugar fermentation tests as described.³⁰

Statistical Analysis

All the analyses were conducted in triplicate and the mean data±SD (standard deviation) were reported.

Results

The result of the physicochemical analysis of the soil samples shows that temperature ranged from 28.6-32.6 °C. The pH values were within the basic range (7.2-10.3). Toxicity of Cassava was highest at the edge (41.3 mg/g) and lowest at the control (24.2 mg/g) while the cyanogenic potential ranged from 0.62 to 5.21 (Table 1). Table 2 presents the physicochemical parameters of the water samples. The result revealed that pH was highest at DSI (7.8) and lowest at DSII (6.7). Temperature ranged from 28.2 °C to 29.1°C while TDS and BOD ranged from 540 mg/L to 175 mg/l and 20 mg/l to 60 mg/L respectively. In the analysis of bacterial diversity, results obtained indicated that total heterotrophic bacteria (THB) have the highest counts in all the soil samples analyzed (Table 3). This group (THB), like all other bacterial groups, increased from 3.7×10⁶ cfu/g (pit edge soil) to 7.4×10⁷ cfu/g in the 100 m away soil. The 100 m away soil value of total heterotrophic bacteria was more than the control in soil. The lipolytic bacteria (LB) count ranged from 0.9×10⁵ cfu/g to 2.4×10⁶ cfu/g, nitrifying bacteria (NB) from 0.4×10⁴ cfu/g to 2.9×10⁴ cfu/g while phosphate solubilizing bacteria (PSB) ranged from 2.2×10⁶ cfu/g to 2.4×10⁶ cfu/g. The bacteria load of the water samples show that the highest counts for THBC and CEUBC (6.7×10⁶ and 4.2×10⁶ respectively) were observed in DSI while the highest count for CBC (2.4×10⁷) was observed in DSII (Table 4). The least bacteria count was obtained in US for CBC (1.5×10⁶), THBC.
(4.5×10^4) and CEUBC (2.1×10^2). The highest occurring grow was the THB, while the least was the coliform. The cassava effluent utilizing bacterial (CEUB) were more than the coliform bacteria (CB). Table 5 presents the bacteria diversity of soil contaminated with the cassava effluent and their prevalence on the various sampling points. The bacteria genera were Escherichia, Enterobacter, Staphylococcus, Lactobacillus, Micrococcus and Bacillus, Alcaligenes, Klebsiella, Corynebacterium and Acinetobacter. Bacillus species was 100% in 5 m away and control, 80% and 70% in pit edge and 10 m away respectively. Also, Corynebacterium, Morexella and Acinetobacter species were not observed in both control and 10 m away while Klebsiella species was isolated in all samples except the control. The bacteria diversity of the water samples contaminated with the effluent shows that Bacillus species was 100% in DS I, 80%, 70% and 60% in DFP, DSII and US respectively (Table 6). The least isolated bacteria were the Alcaligenes in all the sampling points. Corynebacterium, Morexella, Acinetobacter and Klebsiella species were not isolated from the upstream (US).

### Table 1: Physico-chemical characteristics of the soil contaminated with cassava effluent

| Parameter                  | EDGE 5 M | 10 M     | 100 M    | CONTROL |
|----------------------------|----------|----------|----------|---------|
| pH                         | 10.3 ± 0.10 | 10.1 ± 0.01 | 8.4 ± 0.20 | 7.6 ± 0.20 |
| TEMPERATURE (°C)           | 32.6 ± 0.02 | 30.1 ± 0.02 | 29.2 ± 0.02 | 28.7 ± 0.02 |
| TOC (mg/L)                 | 41.3 ± 0.02 | 35.0 ± 0.00 | 30.8 ± 0.01 | 24.4 ± 0.01 |
| C/N Ratio                  | 19.48 ± 0.12 | 15.30 ± 0.10 | 13.12 ± 0.21 | 8.01 ± 0.08 |
| CYNOGENIC POTENTIAL (mg/L) | 5.21 ± 0.09 | 4.66 ± 0.14 | 3.22 ± 0.12 | 0.92 ± 0.06 |

Values are mean of three independent experiments

**Abbreviations:** TOC, toxicity of cassava; C/N Ratio, carbon and nitrogen ratio

### Table 2: Physico-chemical characteristics of the water contaminated with cassava effluent

| Parameter                  | US       | DFP      | DS I     | DS II    |
|----------------------------|----------|----------|----------|----------|
| pH                         | 6.8 ± 0.02 | 7.1 ± 0.01 | 7.8 ± 0.02 | 6.7 ± 0.02 |
| TEMPERATURE (°C)           | 28.2 ± 0.20 | 28.9 ± 0.21 | 29.1 ± 0.09 | 28.8 ± 0.20 |
| TDS (mg/L)                 | 540 ± 0.00 | 1750 ± 0.02 | 1320 ± 0.06 | 920 ± 0.04 |
| TSS (mg/L)                 | 20 ± 0.00  | 60 ± 0.00  | 40 ± 0.00  | 31 ± 0.00  |
| DO (mg/L)                  | 3.0 ± 0.00 | 4.0 ± 0.00  | 25 ± 0.00  | 30 ± 0.01  |
| BOD (mg/L)                 | 20 ± 0.00  | 60 ± 0.00  | 50 ± 0.00  | 30 ± 0.00  |
| CYNOGENIC POTENTIAL (mg/L) | ND       | 1.03 ± 0.04 | 0.42 ± 0.01 | Traces    |

Values are mean of three independent experiments

**Abbreviations:** BOD, biological oxygen demand; DO, dissolved oxygen; TDS, total dissolved solids; TSS, total suspended solids; ND, not detected, US, upstream, DFP, discharge/fallout point; DS I, downstream one, DS II, downstream two.

### Table 3: Bacterial load of soil Samples Contaminated with effluent

| Group   | Edge 5m | 10m | 100m | Control |
|---------|---------|-----|------|---------|
| THB     | 3.7X10^4 | 3.9X10^4 | 3.9X10^5 | 3.4X10^6 |
| LB      | 0.9X10^1 | 0.9X10^1 | 1.7X10^2 | 2.4X10^3 |
| NB      | 0.4X10^1 | 0.4X10^1 | 0.4X10^2 | 2.7X10^3 |
| PSB     | 2.2X10^2 | 2.4X10^2 | 2.4X10^3 | 2.7X10^3 |

**Abbreviations:** THB, total heterotrophic bacteria; LB, lipolytic bacteria; NB, nitrifying bacteria, PSB, phosphate solubilizing bacteria

### Table 4: Bacterial load of water Samples Contaminated with Effluent

| Group   | US       | DFP      | DS I     | DS II    |
|---------|----------|----------|----------|----------|
| CBC     | 1.5X10^2 | 1.7X10^2 | 1.9X10^2 | 2.4X10^3 |
| THBC    | 4.5X10^4 | 4.6X10^4 | 6.7X10^4 | 5.1X10^4 |
| CEUBC   | 2.1X10^2 | 3.7X10^2 | 4.2X10^3 | 3.9X10^4 |

**Abbreviations:** BC, coliform bacterial count; THBC, total heterotrophic bacteria count; CEUBC, cassava effluent utilizing bacteria count; US, upstream, DFP, discharge/fallout point; DS I, downstream one, DS II, downstream two.

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do not differ much from the results obtained in this study, especially as it was cassava effluent that was studied too. The high change in pH and temperature very close to the waste pit could be attributed to the high oxidative and reductive biochemical transformations taking place there. The breakdown of organic matter in the effluent was exothermic, which caused the increase in temperature while the metabolism of the little protein content released ammonia (NH₃). The ammonia dissolved in the available moisture to cause the reported increase in pH value. A similar observation had been reported by in similar studies on cassava effluent.

In biological indices analyzed, results showed that the bio-loads of all the bacterial groups increased with distance away from the waste pit suggesting adverse growth conditions towards the pit, this had been reported.⁴ Values obtained at 100m away were not statistically higher than those from control. This observation suggests that the high content of cassava mill effluent suppressed bacterial growth but at very low concentrations, this suppressed bacterial growth could be due to cumulative effects of some components of the cassava wastes which inhibited the bacterial growth¹⁴ reported that organic matter when added to the soil in small concentrations encouraged bacterial growth. This observation agreed well with this study. Conditions and nutrients at 100m sampling point could have been optimum for bacterial growth, hence the results obtained. Several authors Nwaugo et al.⁴,⁵,¹² have stated that total heterotrophic bacterial counts are in all cases higher than the other specific bacterial groups in the soil. Similarly,¹⁷ reported that very slight change in environmental factors affect nitriying bacteria adversely. THB were the most prevalent in all the soil samples analyzed, NB were the least, NB were the most adversely affected bacterial group in the study. Some bacterial species in the specialized group (LB, NB and PSB) may equally be found in the THB, making the THB more abundant than any other group.

In the water analysis of this work, twelve microbial species were isolated. Most of them had been reported earlier in similar work have observed some of them in fermenting tuber and vegetable. While some are natural saprophytes like Corneybacterium, Bacillus, Micrococcus, Alcaligenes, Acinetobacter and Saccharomyces species could occur due to human activities. Some of the organisms in the water body could have come from the processing plants or effluent as some of them which were not in the US, were found in the DFP and DS samples. Some of the other organisms increased in prevalence in the presence of the cassava effluent indicating that the effluent was utilized as nutrient. This was the case of Alcaligenes, Lactobacillus, Micrococcus and Bacillus species. These organisms were those, which could utilize the effluent. Abiona et al. (2005),¹⁷ stated that effluent from cassava was nutritive enough to support microbial growth, which agree with this work. Cassava effluent supplied both nutrients and organisms to the Nkissa River from the DFP, but was too harsh or in a state not very appropriate for immediate microbial utilization. A similar situation had been reported by.¹⁸-²¹ Highest bio-load occurred in the DSI but decreased in DSII and in DFP was higher than US values. The THB was the highest, followed by CEUB before CB, which was very low. This means that survival of the CB in the downstream portion of the river was due to the metabolism of the intermediates of the effluent. From the results, CB was not utilizers of the cassava effluent. CEUB occurred in the US indicating that the cassava effluent degraders could be found anywhere without the presence of the effluent. However, the presence of the effluent ensured better adaptation to its metabolism hence the increase in number and prevalence.²²-²⁵

**Table 5: Relevance of Organisms Observed in Various Soil Samples Analyzed**

| Organisms       | Control | Pit edge | 5m away | 10m away |
|-----------------|---------|----------|---------|----------|
| Enterobacter sp | 4(40%)  | 2(20%)   | 4(40%)  | 2(20%)   |
| Escherichia sp  | 2(20%)  | 2(20%)   | 3(30%)  | 2(20%)   |
| Staphylococcus sp | 6(60%) | 7(70%)   | 5(50%)  | 5(50%)   |
| Lactobacillus sp | 2(20%) | 8(80%)   | 6(60%)  | 5(50%)   |
| Micrococcus sp  | 2(20%)  | 5(50%)   | 7(70%)  | 7(70%)   |
| Bacillus sp     | 10(100%)| 6(60%)   | 10(100%)| 5(50%)   |
| Alcaligenes sp  | 1(10%)  | 8(80%)   | 5(50%)  | 4(40%)   |
| Klebsiella sp   | -       | 4(40%)   | 4(40%)  | 3(30%)   |
| Corynebacterium sp | -     | 5(50%)   | 6(60%)  | -        |
| Morexella sp    | -       | 5(50%)   | 2(20%)  | -        |
| Aemietobacter sp | -      | 5(50%)   | 4(40%)  | -        |

**Table 6: Diversity of Bacteria from Effluent Contaminated Water**

| Organisms       | US | DFP | DS I | DS II |
|-----------------|----|-----|------|-------|
| Enterobacter sp | 5(50%) | 2(20%) | 3(30%) | 2(20%) |
| Escherichia sp  | 4(40%) | 2(20%) | 4(40%) | 2(20%) |
| Staphylococcus sp | 4(40%) | 6(60%) | 7(70%) | 5(50%) |
| Lactobacillus sp | 2(20%) | 5(50%) | 7(70%) | 5(50%) |
| Micrococcus sp  | 2(20%) | 5(50%) | 7(70%) | 5(50%) |
| Bacillus sp     | 6(60%) | 8(80%) | 10(100)% | 7(70%) |
| Alcaligenes sp  | 1(10%) | 3(30%) | 5(50%) | 5(50%) |
| Klebsiella sp   | -    | 2(20%) | 4(40%) | 4(40%) |
| Corynebacterium sp | - | 3(30%) | 5(50%) | 5(50%) |
| Morexella sp    | -    | 2(20%) | 2(20%) | 2(20%) |
| Aemietobacter sp | -    | 2(20%) | 4(40%) | 2(20%) |

**Abbreviations:** US, upstream; DFP, discharge/fallout point; DS I, downstream one; DS II, downstream two
Conclusion
This study therefore revealed adverse environmental effects of cassava mill effluent on soil biological parameters. Again, it also calls for serious rehabilitation, if the soil will be used for agricultural and other purposes as the factors important in soil health are negatively affected. The results obtained indicated that similar organisms were observed in each environment. Further observations in the study suggest the need for proper legislation against indiscriminate disposal of industrial wastes into our environment whether organic or inorganic, biodegradable or not.

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Conflict of interest
The author declares there is no conflict of interest.

References
1. Abiona OO, Sanni LO, Bamgboye O. An evaluation of microbial load and cyanide contents of water sources, effluents and peels three cassava processing location. J Food Agric Environ. 2005;3(1):207–208.
2. Oyewole OB, Afolami OA. Quality and Preference of different cassava varieties for Lafun production. Afr J Food Tech. 2003;6:27–29.
3. Desse G, Tay M. Microbial loads and Microflora of cassava and effects of cassava juice on some food borne pathogens. J Food Tech Afr. 2001;6(1):21–24.
4. Aderiye BI, Laley SA. Relevance of fermented food products in southwest Nigeria. Plant Foods Hum Nutri. 2003;58(3):1–16.
5. Aderiye OK. Hematological and Histopathological effects of cassava mill effluents in Claria gariepinus. Afr J Biomed Res. 2005;8(3):179–183.
6. Nwabueze TU, Odansi FO. Optimization of process conditions from cassava (Manihot esculenta) Lafun production. Afr J Biotech. 2007;6(5):603–611.
7. Akani NP, Nmelo SA, Ihemanandu IN. Effects of cassava processing effluents on the microbial population and physicochemical properties of loamy soil in Nigeria. 10th Annual Conf Nig Soc Microbiol, Keffi, 10-14th October, Nigeria; 2006.
8. Nwaugo VO, Onyeagba RA, Chima GN. Effects of discharge of Petroleum produced water on the physicochemical and potential flora of Nkissa River, Egbema, Rivers State. Int J Biotechnol Allied Sci. 2007;2(2):126–130.
9. Walkey A, Black P. A Critical Examination of a Rapid Method of Determining Organic Carbon in Soils. Soil Science. 1947;63:251–265.
10. Cowan ST, Steel S. Manual for identification of Medical Bacterial. Cambridge University. USA; 1993.
11. Oluosos OA. Understanding Soil and Plant Nutrition. Salmon Press and Co. Nigeria. LTD. 2009. p. 12–16.
12. Nwaugo VO, Chinyere GC, Inyang CU. Effects of palm oil mill effluent (POME) on soil bacterial flora and enzyme activities in Egbema River State. Plant Prod Res J. 2008;10:928–934.
13. Aderiye JB, Oluduro AO, Owolabi OA. Biochemical and microbiological composition of fermented cassava tuber and survival of pathogenic Staphylococcus aureus in garri. J Appl Environ Sci. 2005;1:1–5.
14. Chinyere GC. Effects of Effluents from cassava processing plants on soil cyanide levels. A case study of Okigwe in Imo State, Nigeria. J Hith Vis Sci. 2001;3:38–93.
15. Karin N. Impact of organic waste residue on structure and function of soil bacterial communities. Ph.D. Thesis Swedish University of Agricultural Sciences, Uppsala, Sweden; 2002.
16. Prescott LM, Klein DA, Harley JP. Microbiology. 6th Edition. McGraw Hill Education Books. USA, 2005. p. 316–386.
17. Oyewole OB, Odunfa SA. Characterization and distribution of lactic bacteria in cassava fermentation during fufu production. J Appl Bacteria. 1992;68(2):148–152.
18. Nwaugo VO, Onyeagba RA, Nwachukwu N C. Effects of Petroleum Produced water on microbial spectrum of Nkissa River, Egbema Rivers State. 28th Annual Conference Nig Soci Microbiol. Ambrose Alli University Ekpoma, Edo State, Nigeria. 2005.
19. Li H, Zhang Y, Zhang CG. Effects of petroleum containing waste water-irrigation on bacterial diversities and enzymatic activities in paddy soil irrigation area. J Environ Qual. 2005;34:1073–1080.
20. Muhungu NM, Yamaguchi Y, Almazan AN. Reduction of cyanide during processing of cassava in Traditional African Foods. J Food Agric. 1987;11:11–15.
21. Nwaugo VO, Onyeagba RA, Obinali M, et al. Effects of calcium carbide wastes on soil Nitrifying bacteria in Okigwe, Imo State. J Appl Sci. 2004;7:4451–4458.
22. Nwaugo VO, Onyeagba RA, Nwachukwu NC. Bacteriological quality of cercarial (S. haematobium) infected abandoned quarry pit water. J Sci Eng Tech. 2006;13:6697–6706.
23. Taye M. Cassava in Southern and Southwestern Ethiopia. Cassava News Letter. 1994;18:6–9.
24. Theroux F, Eldridge E. Laboratory manual for chemical and bacterial analysis of water and sewage. McGraw- Hill, New York. 1998.
25. Olayiwola OA, Odulipo MA. Uptake of cyanogenic potential by soil in cassava (Manihot esculenta crantz) producing sites and health implications. Res J Agric Environ Managt. 2013;2(7):190–196.

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