EFFECT OF CASSAVA PROCESSING WASTE ON SOIL PHYSICAL, CHEMICAL PROPERTIES AND MICROBIAL POPULATION IN SELECTED CASSAVA PROCESSING MILLS IN AKWA IBOM STATE

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ABSTRACT
This study investigated the effects of cassava processing waste (CPW) on soil physico- chemical properties and microbial populations. Soil samples were collected from the depths of 0-15 cm and 15-30 cm from areas with and without CPW disposal. Analysis revealed significant alterations in soil chemical properties, including increased organic carbon, nitrogen, and phosphorus, and decreased pH. Microbial populations were also affected, with increased bacterial and fungal counts found in CPW-affected soils. The analysis demonstrates that cassava processing waste has resulted in an increase in soil pH at both 0-15 cm and 15-30 cm depths in polluted soils compared to unpolluted soils. Microbial population showed a positiveand significant correlation with nitrogen (N) (r =0.51, (p<0.05), organic carbon (OC) (r = 0.81, (p<0.01), and organic matter (OM) (r = 0.81, (p<0.01), and negative and non-significant correlation with clay (r= -0.36, (p>0.05) and available P (r =-0.12, (p>0.05). This result implies that an increase in microbial population will subsequently increase the level of N, OC and OM in the soil. The findings from this study showed that cassava processing waste significantly enhances microbial populations in the upper soil layers, likely due to the organic matter and nutrients present in the effluent, which can stimulate microbial growth. It is recommended that integrated waste management practices should be implemented, including composting, anaerobic digestion, or other treatment methods. Regular soil testing and monitoring should be conducted to assess the impact of CPW disposal.

Keywords: Cassava effluent, microbial population, soil management

INTRODUCTION

Cassava serves as an important food security crop in Nigeria. However, before it is consumed, it isprocessed intodiverse products including traditional delicacies and industrialproducts like garri, fufu, starch,chips, pellets, cake, flour etc, some of which arefermented products (Akpan *et al.,* 2017). The processing of cassava into other products, for example garri involves several unit operations vis-a-vis, peeling, washing, grating, pressing and fermenting, sieving, roasting and drying (Akpan *et al.,* 2017), traditionally generate a lot of waste (e.g water, hydrocyanic acid, peels and sieves from the pulp) from cassava mills which are usuallydischarged on land indiscriminately and this inturn affects soil and groundwater including biota(plant and micro-organism) within theconfinement where such activities are carriedout (Olorunfemi *et al.,* 2008; Obueh and Odesiri-Eruteyan, 2016). Moreover, the presence of cyanogenic compounds in cassava waste can introduce toxic elements into the soil environment. High concentrations of cyanide have been reported in soils receiving cassava effluents, which can inhibit the growth of beneficial soil microorganisms and disrupt the overall microbial community structure (Obueh and

Odesiri-Eruteyan, 2016; Akpan *et al.,* 2017). This toxicity not only affects soil chemistry but also poses risks to plant health and agricultural productivity.

Cassava mill effluent (CME) from traditional grating during processing is a major cause of environmental degradation, contaminating agricultural farmlands, streams and affecting biodiversity (Chinyere *et al.*, 2013; Akpan and Udoh, 2017). The CME mostly contains large amount of water, hydrocyanic acid and organic matter. When cassava mill effluents are improperly disposed, they generate offensive odour and unwanted scene (Okafor, 2008). They are potential hazard to soil, water, flora, fauna, livestock and human population living around the processing locations (Omonoma and Akipelu, 2010).

Knowing that cassava effluent constitutes environmental problem, it is therefore pertinent to ascertain the effect of cassava waste on soil physico-chemical properties and microbial populations, which are the key indicators of productive soils and thus calls for regulation in the discharge of the waste generated. Soil gets the ultimate impacts of the toxicants from cassava processing and other industrial effluents and this is detrimental to agricultural activities in the area where such activities are carried out. Top soil (0-20 cm) consists of large proportion of microorganisms which are involved in the degradation of organic matter and nutrient cycling. Long-term discharge of this effluent into the soil could result in a serious imbalance in the microbial population, which in turn could result in alteration of soil fertility toward a negative direction. Studies that have been carried out on the effect of cassava effluent on soils properties have consistently showed that there are always some microbial changes in the soil properties when the effluent are discharged on it, notably examples are those conducted by Ebhoaye *et al.*, (2004) and Nwakauda *et al.*, (2012).

This however, shows that cassava mill effluent discharge has the tendencies to alter soil properties causing changes in soil pH and microbial loads (Okechi *et al.*, 2011). Reports have shown that the cassava effluent contains harmful cyanides, copper, mercury and nickel which have the capacity to affect native micro-biota (Aiyegoro *et al.*,2007). Cassava processing effluence can have significant impacts on soil chemical properties, affecting fertility and productivity. However, cassava processing generates large amounts of effluence, which can pollute soil, water, and air if not managed properly. Studies by Iyagba *et al.*, (2018) andOguntimehin *et al.*, (2020), among others, have also shown that Cassava effluence can increase soil nutrient availability, particularly nitrogen, phosphorus, potassium andalter soil pH, making it more acidic. The acidity is attributed to the high levels of organic acids, such as citric and malic acids, present in the effluence. However, excessive application of these nutrients can lead to nutrient imbalances and environmental pollution. Cassava effluence can contaminate soil with heavy metals, such as lead, cadmium, and chromium (Adeogun *et al.*, 2019). These metals can accumulate in soil and pose risks to human health and the environment. However, the effluent generated from cassava processing can have negative impacts on the environment, particularly on soil chemical properties. A study conducted in Nigeria found that cassava effluent reduced soil pH from 6.5 to 5.5 after 12 weeks of application (Oguntimehin *et al.*, 2020). Cassava effluent can also significantly increase soil organic matter content (Oyewole *et al.*, 2017). Thus, proper management and treatment of the effluence are necessary to mitigate these effects and ensure sustainable cassava production. It is with this background that this research was design to assess the effect of cassava processing waste on soil physico- chemical properties, microbial population(bacteria and fungi), and establish the relationship between soilphysico- chemical properties and soil microbial population.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in two locations of cassava processing waste impacted soils located in Ikot Ekpene local government and Oruk Anam local Government both in Akwa Ibom state. The selected areas have received cassava effluent for a minimum of ten (10) years.

Soil Sampling and Preparation

Composite soil samples were collected from 0-15 and 15-30cm depth from two soils impacted with effluent discharge from cassava waste and a non-impacted soil which serves as the control. The soils samples were air dried, crushed and sieved using a 2mm mesh sieve and stored in well label polythene bags for routine soil analysis.

Analysis of soil physical and chemical properties

Particle size analysis was determined by mechanical analysis technique of Bouyocous modified by Gee and Or (2002) using sodium hexa-metaphosphate as a dispersant. Soil pH was measured potentiometrically in a soil: water suspension (mixed at a ratio of 1:2.5 soil: water) using glass electrode pH meter following the procedure described by Udo *et al*. (2009). Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black as outline in Nelson and Sommers (1996). Total nitrogen content of the soil was determined by wet-digestion, distillation and titration procedures of the Kjeldahl method as described by Bremner (1996). Available phosphorus (P) was extracted by Bray-1 method and the colour was developed in soil extract using ascorbic acid blue method (Kuo, 1996). . Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N ammonium acetate (NH_4OAc) at pH 7.0 using 1:10 soil-liquid ratio. Calcium and Mg in the extract were determined by EDTA (Ethylene Diaminetetra Acetate Acid) titration method while Na and K in the extract were determined using a flame photometer.

Analysis of Soil microbial properties

Enumeration of total heterotrophic bacteria and fungi

The total aerobic bacteria and fungi counts were carried out using pour plate techniques as described by Fawole and Oso (2004), after ten-fold serial dilution. The media of choice were oxoid Nutrient agar.Agar-Agar extract and saboroud Dextrose agar, prepared according to the manufacturer's instruction.

Characteristics and identification of microbial isolates.

The bacteria isolates were identified by Biochemical test (gram reaction, motility, indolent, catalase, coagulase, oxidase, urease and citrate).The resultant characteristics were compared with those of known taxa using the keys provided in the Bergeys manual of Determinatives Bacteriology by Holt *et al*.,(1994)and the scheme of cheesbrough.(2005).The cultural characteristics of the bacteria isolated were compared with cultural characteristics presented by Dubey andMaheshwari(1999).Fungal isolates were examined macroscopically and microscopically using the needle mounts techniques. The identification was performed according to the scheme of Barnett and Hunter. (1986).

Statistical Analysis

Data collected were analyzed using descriptive statistics(mean, standard deviation and coefficient of variation) and bar chart.

RESULTS AND DISCUSSION

Effect of cassava processing waste on soil physical properties

Soil physical properties of soil contaminated with cassava processing waste is presented in Table 1. The result showed that polluted soil at 0-15 cm soil depth in Ikot Ekpene exhibited 86.8gkg sand, whereas unpolluted soil contained 83.8g/kg sand. Similarly, in Oruk Anam, at 0-15 cm soil depth, polluted soil exhibited 85.3g/kg sand, whereas unpolluted soil contained 79.8g/kg sand. This increase in sand contents in polluted soils may indicate a reduction in finer soil particles, potentially due to erosion or leaching processes exacerbated by the cassava effluent. However, at 15-30 cm soil depth, Ikot Ekpene polluted soil had 80.8g/kg sand, whereas unpolluted soil contained 81.3g/kg sand. Similarly, in Oruk Anam, at 15-30 cm soil depth, polluted soil exhibited 81.8g/kg sand, whereas unpolluted soil contained 80g/kg sand.The higher sand content in polluted soil could lead to increased drainage and reduced water retention capacity, which may adversely affect plant growth. Sandy soils typically have lower nutrient-holding capacity, which can be detrimental in agricultural contexts where nutrient availability is crucial for crop yields.Studies indicate that soils impacted by cassava processing waste often exhibit a higher proportion of sand compared to silt and clay. Edwin *et al.,*(2022) reported a distribution of 67.73% sand, 16.77% silt, and 15.5% clay in CME affected soils, suggesting that cassava waste tends to enhance the sandy texture of soils.

Table 1: Effect of cassava processing waste on soil physical properties

Location		Sand (g/kg)			Silt (g/kg)			Clay (g/kg)		
	Depth	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Oruk Anam polluted	0-15	85.3	0.71	0.83	7.5	0.71	9.43	7.2	1.41	19.64
Ikot Ekpene polluted	0-15	86.8	1.41	1.63	7	1.41	20.20	6.2	0.00	0.00
Oruk Anam unpolluted	0-15	79.8	0.00	0.00	8	0.00	0.00	12.2	0.00	0.00
Ikot Ekpene unpolluted	0-15	83.8	0.00	0.00	6	0.00	0.00	10.2	0.00	0.00
Oruk Anam polluted	15-30	81.8	2.83	3.46	11	1.41	12.86	7.2	1.41	19.64
Ikot Ekpene polluted	15-30	80.8	1.41	1.75	10	2.83	28.28	9.2	1.41	15.37
Oruk Anam unpolluted	15-30	80.3	0.71	0.88	4.5	0.71	15.71	15.2	1.41	9.30
Ikot Ekpene unpolluted	15-30	81.3	0.71	0.87	5.5	0.71	12.86	13.2	1.41	10.71

SD= standard deviation, CV (%) = coefficient of variation

Silt contents

The effect of soil contaminated with cassava processing waste on silt content is presented in Table 1. The polluted soil at 0-15 cm soil depth in Ikot Ekpene had 7g/kg silt whereas unpolluted soil contained 6g/kg silt. Similarly, in Oruk Anam, at 0-15 cm soil depth, polluted soil exhibited 7.5g/kg silt, whereas unpolluted soil contained 8g/kg silt. However, at 15-30 cm soil depth, Ikot Ekpene polluted soil had 10gkg silt, whereas unpolluted soil contained 5.5gkg silt. In Oruk Anam, at 15-30 cm soil depth, polluted soil exhibited 11g/kg silt, whereas unpolluted soil contained 4.5g/kg silt.The increase in silt content in the polluted soil, particularly at both depths, suggests that the cassava processing waste may have contributed additional fine particles to the soil. This could be due to the organic matter and other fine materials present in the waste, which can enhance silt levels. The higher silt percentage at 15-30 cm depth (10g/kg and 11g/kg) in polluted soils compared to the upper layer (7g/kg and 6g/kg) indicates potential leaching or downward movement of silt particles, possibly influenced by water infiltration from rainfall or irrigation. This movement can alter the soil profile and affect nutrient distribution. In unpolluted soil, the silt content is lower at both depths (e.g., 6g/kg and 5.5g/kg), indicating a more stable composition without the influence of external waste inputs. This stability is crucial for maintaining soil structure and fertility (Edwin *et al.,* 2022). The presence of higher silt contents in polluted soils can affect soil texture and structure. Silt particles contribute to improved water retention compared to sand but can also lead to compaction if present in excess, potentially affecting root growth and aeration. Higher silt content can make soils more susceptible to erosion, especially if they become saturated with water. This is a concern for agricultural practices where soil conservation is vital for sustainable crop production (Osakwe, 2012). In addition, changes in silt content may also influence microbial communities within the soil. Higher silt levels can provide a habitat for various microorganisms that contribute to nutrient cycling, but pollutants may disrupt these beneficial processes.

Clay content

The effect of soil contaminated with cassava processing waste on clay content is presentedin Table 1. In Ikot Ekpene soils, the polluted soil shows a decrease in clay content at both depths, with 6.2g/kg at 0-15 cm and 9.2g/kg at 15-30 cm, compared to higher levels in unpolluted soil (10.2g/kg and 13.2g/kg, respectively). This reduction may indicate a loss of finer particles due to erosion or leaching processes, potentially exacerbated by the application of cassava processing waste. However, in Oruk Anam, the polluted soil at both depths had 7.2g/kg clay content, whereas in unpolluted soil, 0-15 cm depth had 12.2g/kg clay while 15-30 cm depth had 15.2g/kg clay. The introduction of cassava processing waste may alter the soil's physical structure, leading to a decline in clay content (Osakwe, 2012). This could be due to the binding properties of organic matter in the waste, which may displace or aggregate clay particles, resulting in their reduced presence. Notably, the unpolluted soil maintains higher levels of clay, which is essential for various soil functions, including nutrient retention, water holding capacity, and overall soil structure stability. The presence of clay is crucial for supporting plant growth as it provides essential nutrients and helps maintain moisture. The differences in clay content suggest that polluted soils may experience altered textural properties, potentially leading to increased drainage and reduced water retention capacity compared to unpolluted soils (Famuyini, and Sedara, 2022). This can adversely affect crop growth, particularly in dry conditions. Clay particles are vital for holding nutrients within the soil matrix. The decrease in clay content in polluted soils could lead to lower nutrient availability for plants, impacting agricultural productivity.

Effect of cassava processing waste on soil chemical properties

Soil pH

The effect of soil contaminated with cassava processing waste on soil pH is presented in Table 2. In Ikot Ekpene soil, the pH levels in polluted soils were 7.1 and 7.75 at 0-15 cm depth and 15-30 cm depth, respectively, while unpolluted soils had a pH value of 6.4 and 6.65 at 0-15 cm depth and 15-30 cm depth, respectively. The increase in pH in polluted soils suggests that the cassava processing effluent may have contributed to a more alkaline environment, likely due to the presence of certain minerals and organic compounds that influence soil chemistry. The polluted soil exhibits a higher pH compared to unpolluted soil, with values of 7.1 at 0-15 cm and 7.75 at 15-30 cm depths. This increase indicates a shift towards a more alkaline environment, which can be attributed to the composition of cassava processing waste. The organic matter present in cassava waste may contribute to higher pH levels through the release of basic cations (such as calcium and magnesium) during decomposition, which can neutralize acidity in the soil (Adekanye *et al.,* 2013; Antonangelo *et al.,* 2024).

Similarly, in Oruk Anam soil, polluted soil had elevated pH than unpolluted soil. The polluted soil exhibits a higher pH compared to unpolluted soil, with values of 6.8 at 0-15 cm and 6.71 at 15-30 cm depths. While unpolluted had a pH of 4.3 at 0-15 cm and 5.25 at 15-30 cm depths. The unpolluted soil has lower pH values (4.3 at 0-15 cm and 5.25 at 15-30 cm), indicating a typical situation for many natural soils, especially in tropical regions with acid sand parent materials. Soil pH is a critical factor influencing nutrient availability for plants. The higher pH in polluted soils may enhance the availability of certain nutrients (e.g., phosphorus), while potentially limiting others (e.g., iron and manganese), which are more available in acidic conditions (Famuyini and Sedara, 2022). The analysis demonstrates that cassava processing waste has resulted in an increase in soil pH at both 0-15 cm and 15-30 cm depths in polluted soils compared to unpolluted soils. This shift towards a more alkaline environment can have significant implications for nutrient availability, plant growth, and overall soil health.

Total nitrogen

The effect of soil contaminated with cassava processing waste on total nitrogen is presented in Table 2. In Ikot Ekpene soil, at a depth of 0-15 cm, the polluted soil has a higher TN level (0.147%) compared to the unpolluted soil (0.126%). This indicates that pollution may have contributed to an increase in nitrogen content at this depth. At a depth of 15-30 cm, both polluted and unpolluted soils have the same TN level of 0.155%. This suggests that pollution may not significantly affect nitrogen levels at greater depths, or that other factors could be influencing nitrogen retention. Similarly, in Oruk Anam soil, at a depth of 0-15 cm, the polluted soil has a higher TN level (0.217 %) compared to the unpolluted soil (0.12 %). This indicates that pollution may have contributed to an increase in nitrogen content at this depth. However, for unpolluted soil, TN at a depth of 0-15 was 0.12 % which is higher than the one observed for deeper layer (15-30 cm), which was 0.091 %. The consistency of TN levels at deeper depths indicates that the impact of pollution may be more pronounced near the surface, potentially affecting root systems and microbial activity. The data suggests that pollution has a measurable effect on total nitrogen levels in soil, particularly at shallower depths. Understanding these variations is crucial for soil management and remediation strategies, especially in agricultural and ecological contexts. The result obtain in this study is in line with those of Obueh and Odesiri-Eruteyan (2016), Edwin *et al*. (2022) and Famuyini, and Sedara (2022).

Available phosphorus

The effect of soil contaminated with cassava processing waste on available phosphorous is presented in Table 2. In Ikot Ekpane soil, at 0-15 cm depth, the polluted soil has a phosphorus level of 84.7 mg/kg, which is higher than the unpolluted soil value (80.05 mg/kg). This difference of 4.65 mg/kg suggests that pollution may have contributed to an increase in phosphorus availability in the upper soil layer. However, at 15-30 cm soil depth, the polluted soil shows a phosphorus level of 86.06 mg/kg, compared to the unpolluted soil's 90.09 mg/kg. The findings indicate that pollution has altered phosphorus dynamics in soils, with higher levels observed in polluted soils at shallow depths compared to unpolluted soils. While this may provide short-term benefits for plant growth, it raises concerns about long-term soil health and environmental impacts associated with nutrient runoff.

However, in Oruk Anam soil, at 0-15 cm depth the polluted soil has a phosphorus level of 70.9 mg/kg, which is higher than the unpolluted soil's

54.38 mg/kg. This difference of 16.52 mg/kg indicates that pollution may have enriched the upper layer of the soil with phosphorus, potentially from cassava waste. Similarly, at 15-30 cm depth, the polluted soil shows a phosphorus level of 80.4 mg/kg, compared to the unpolluted soil's 50.05 mg/kg. Here, the difference is even more pronounced at 30.35 mg/kg, suggesting that phosphorus levels in polluted soils not only exceed those in unpolluted soils at both depths but also increase with depth in the polluted soils. This observation corroborates with the study of Famuyini and Sedara (2022).

Phosphorus is a critical nutrient for plant growth, playing essential roles in energy transfer, photosynthesis, and nutrient transport within plants (Obueh and Odesiri-Eruteyan, 2016). The increased phosphorus levels in polluted soils at the surface may enhance initial plant growth; however, if these levels are due to pollution from organic or inorganic sources, there could be long-term consequences for soil health.

Table 2: Effect of cassava processing waste on soil chemical properties

Location		pH			P (mg/kg)			N (%)		
	Depth	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Oruk Anam polluted	0-15	6.8	0.14	2.08	70.9	0.00	0.00	0.22	0.01	4.56
Ikot Ekpene polluted	0-15	7.1	0.14	1.99	84.7	0.00	0.00	0.15	0.01	6.73
Oruk Anam unpolluted	0-15	4.3	0.14	3.29	54.38	0.03	0.05	0.11	0.00	0.00
Ikot Ekpene unpolluted	0-15	6.4	0.14	2.21	80.05	0.07	0.09	0.13	0.02	15.71
Oruk Anam polluted	15-30	6.71	0.13	1.90	86.4	3.54	4.09	0.24	0.01	3.01
Ikot Ekpene polluted	15-30	7.75	0.21	2.74	86.05	0.07	0.08	0.16	0.01	4.56
Oruk Anam unpolluted	15-30	5.25	0.35	6.73	50.05	0.07	0.14	0.09	0.01	10.88
Ikot Ekpene unpolluted	15-30	6.65	0.07	1.06	90.9	0.00	0.00	0.16	0.01	4.56

SD= standard deviation, CV (%) = coefficient of variation

Soil organic carbon

The results for organic carbon (OC) are presented in Fig. 1. These results compare the OC levels in polluted and unpolluted soils at two depths: 0-15 cm and 15-30 cm. In Ikot Ekpene soil, the OC levels in both polluted and unpolluted soils show variation with depth. In polluted soil, there is a slight increase in OC from the 0-15 cm depth to the 15-30 cm depth (from 1.20% to 1.28%). In unpolluted soil, the OC decreases from the 0-15 cm depth to the 15-30 cm depth (from 1.24% to 1.15%).However, in Oruk Anam soils, the polluted soil shows higher OC levels compared to the unpolluted soil. At 0-15 cm depth polluted soil had OC (3.4%) compared with unpolluted with 1.08 % OC. Also, at 15-30 cm depth, polluted had 2.65 % OC compared to unpolluted soil with 1.03 % OC. This suggests that pollution may have contributed to an increase in organic carbon content, possibly due to the introduction of organic waste materials in the waste or changes in microbial activity. This observation is in line with what was reported by Obueh and Odesiri-

Eruteyan, (2016) and Famuyini and Sedara, (2022). In both polluted and unpolluted soils, the OC percentage decreases with depth. This is a common trend as organic matter tends to accumulate in the topsoil due to biological activity (Edwin *et al.,* 2022).

Exchangeable calcium

The results of exchangeable calcium (exch. Ca) levels in polluted and unpolluted soils is presented in Fig. 1. This resultreveal significant differences that can impact soil health and agricultural productivity. In polluted soil in Ikot Ekpene, at a depth of 0-15 cm, the exch. Ca was 7.4 cmol/kg, while at 15-30 cm, it increased to 9.4 cmol/kg. This pattern indicates a slight recovery of calcium levels with depth. In contrast, the unpolluted soil showed higher levels of exch. Ca, with 11.8 cmol/kg at 0-15 cm and 14.6 cmol/kg at 15-30 cm. The difference in calcium levels between the polluted and unpolluted soils underscores the negative impact of pollution on nutrient availability. However, for polluted soil in Oruk Anam, the result showed higher exch. Ca level (9.8 cmol/kg) compared to the unpolluted soil (2.6 cmol/kg), with a difference of 7.2 cmol/kg. This suggests that pollution from cassava processing wastes may have introduced or mobilized calcium in the upper soil layer. Consequently, at 15-30 cm depth, the polluted soil still shows higher exch. Ca (6.0 cmol/kg) than the unpolluted soil (3.4 cmol/kg), with a difference of 2.6 cmol/kg. However, the decrease in calcium levels from the upper to lower layers in polluted soil indicates potential leaching or nutrient depletion at greater depths.

The elevated levels of exchangeable calcium in the polluted soil, particularly at the surface layer of Oruk Anam soil, can have both beneficial and adverse implications. Higher calcium levels can enhance soil structure and improve nutrient availability for plants, as calcium plays a crucial role in cell wall stability and nutrient uptake processes (Osakwe, 2012). However, excessive calcium may also lead to competition with other essential cations such as magnesium (Mg) and potassium (K), potentially resulting in nutrient imbalances that could affect plant health and growth (Famuyini and Sedara, 2022). The findings of this study indicate that pollution has altered the exchangeable calcium dynamics in soils, leading to elevated levels in the upper layers of polluted soils compared to their unpolluted counterparts (as observed in Oruk Anam soil). While higher calcium availability can benefit certain crops, it is crucial to monitor and manage potential nutrient imbalances that may arise from these changes.

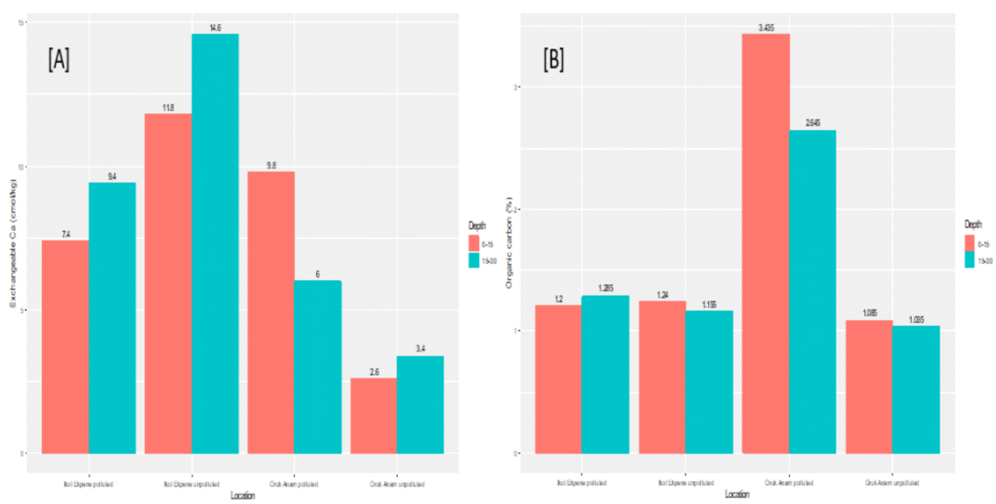

Fig. 1: Effect of cassava processing waste on [A] soil exchangeable ca and [B] soil organic carbon

Effect of cassava processing waste on soil microbial population

The microbial populations of the studied soils are presented in Table 3. The result showed soil polluted with cassava processing waste to exhibit elevated microbial population compared to unpolluted soils. In polluted soils in Oruk Anam, the microbial population of 4.43×10^9 CFU/g was observed at a depth of 0-15 cm and 3.45×10^6 CFU/g at 15-30 cm depth. In contrast, unpolluted soils showed much lower microbial populations of 1.38×10^5 CFU/g at 0-15 cm and 1.43×10^5 CFU/g at 15-30 cm depth. The findings from this study indicates that cassava processing waste significantly enhances microbial populations in the upper soil layers, likely due to the organic matter and nutrients present in the effluent, which can stimulate microbial growth. Similarly, in Ikot Ekpene soils, the data indicates that the microbial population in polluted soil is substantially higher than in unpolluted soil. Specifically, at a depth of 0-15 cm, the polluted soil had a microbial population of 2.51×10^6 CFU/g, compared to 1.58×10^4 CFU/g in unpolluted soil. At a depth of 15-30 cm, the values were 1.63×10^7 CFU/g for polluted soil and 2.45×10^4 CFU/g for unpolluted soil. This differences suggests that cassava processing waste significantly enhances microbial activity in the soil. Similar observation was reported byNweke and Onuoha, (2024).

The microbial population in polluted soils was notably higher, suggesting enhanced microbial activity due to the organic matter present in cassava waste. Higher microbial populations can enhance nutrient cycling, potentially increasing the availability of nutrients such as nitrogen and phosphorus. However, this can also lead to imbalances if certain microorganisms proliferate excessively due to the specific conditions created by the waste. The presence of pollutants like hydrogen cyanide from cassava waste can inhibit beneficial microbes and disrupt natural processes. The microbial populations in cassava-polluted soils typically show a marked increase in bacterial counts compared to unpolluted soils. For example, bacterial populations were found to be significantly higher in contaminated sites (Table 3). In contrast, fungal populations were generally lower, indicating that bacteria may thrive more effectively in the altered chemical environment created by cassava waste (Nweke and Onuoha, 2024).

Table 3: Effect of cassava processing waste on soil microbial population

Location	Depth	Microbial count	(CFU/g)	microbial/insolate
Oruk Anam polluted	0-15	4.43×10^9		Acinetobacter spp, Cyanobacteria, Blastochloris sulfoviridis, Rhizopus indicus, Mucor indicus
Ikot Ekpene polluted	0-15	2.51×10^6		Mycobacterium spp, Bacillus subtilis, cyanobacteria spp, Sulfoviridis spp
Oruk Anam unpolluted	0-15	1.38×10^5		Bacillus spp, Enterobacter cloacae Streptococcus faecalis, Eshericia coli
Ikot Ekpene unpolluted	0-15	1.58×10^4		Salmonella spp, campylobacter spp, Escherichia coli, Pseudomonas aeruginosa spp.
Oruk Anam polluted	15-30	3.45×10^6		Rhizopus indicus, Mucor indicus
Ikot Ekpene polluted	15-30	1.63×10^7		Sulfoviridus spp, mycobacterium spp, cyanobacteria spp.
Oruk Anam unpolluted	15-30	1.43×10^5		Salmonella, Pseudomonas aeruginosa, staphylococcus spp.
Ikot Ekpene unpolluted	15-30	2.45×10^4		Staphylococcus aureus, klebsiella spp.

Relationship between soil chemical properties and microbial population

A bivariate linear correlation (Pearson correlation) analysis was performed among the studied soil properties to assess their linear relationship (Fig. 2). Microbial population showed a positiveand significant correlation with Nitrogen (N) (r =0.51, p<0.05), organic carbon (OC) (r = 0.81, p<0.01), and OM (r = 0.81, p<0.01), and negative and non-significant correlation with clay (r= -0.36, p>0.05) and available P (r =-0.12, p>0.05). This result implies that an increase in microbial population will subsequently increase the level of N, OC and OM in the soil. Other notably relationships were also observed. For example, a positive and significant relationship between exchangeable pH and Ca, and P implies that an increase in soil pH, will correspondingly increase the values of soil Ca and P, and vice versa. Similarly, a negative and significant relationship between clay and sand, silt, pH, N, OC and OM implies that an increase in clay content will correspondingly decrease the values of those properties, and vice versa.The application of cassava waste generally increases the organic carbon and nitrogen contents in the soil. Higher OC levels was found to enhance microbial growth in many studies (Ogboghodo *et al.,* 2006; Nweke and Onuoha, 2024), this is so because many microorganisms rely on organic matter as a food source. However, the relationship between OC and microbial populations can be complex; while increased OC may support more diverse microbial communities, extremely high levels of pollution can lead to toxic conditions that suppress certain microbial groups (Nweke and Onuoha, 2024).

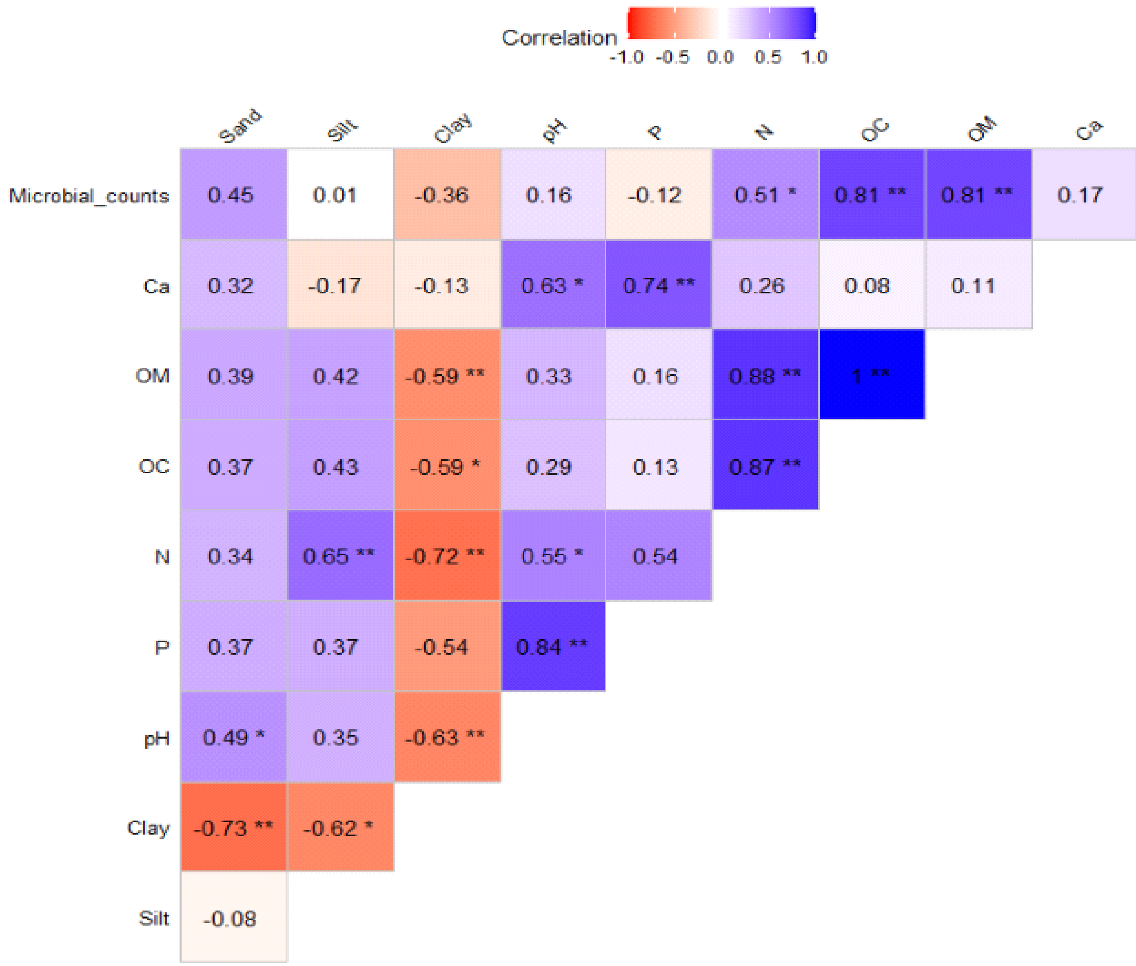

Figure 2: Correlation matrix plot showing relationship between studied soil properties and microbial population

Note: * Significant at P ≤ 0.05; ** significant at P≤ 0.01

Conclusion

The findings from this research indicated that the disposal of cassava processing waste alters soil chemical properties and microbial populations. There was marked increased in most of the soil properties. The increase in organic carbon, nitrogen, and phosphorus can enhance soil fertility, but the decrease in pH may have adverse effects on soil health. The increase in microbial populations can also improve soil structure and fertility. However, improper management of Cassava mill effluent (CME) disposal can lead to environmental pollution and soil degradation. Therefore, it is essential to develop sustainable management practices for Cassava mill effluent (CME) disposal to minimize its environmental impact while harnessing its potential benefits for soil health and fertility.

REFERENCES

Adekanye, T. A., Ogunjimi, S. I. & Ajala, A. O. (2013). An assessment of cassava processing plants in Irepodun Local Government Areas, Kwara State, Nigeria.*World J Agri Res*, 1: 14-17.

Adeogun, S. O., Adewumi, M. O. & Oluwaseun, A. A. (2019). Impact of Climate Change on Cassava (Manihot esculenta Crantz) Production in Southwest Nigeria. *Journal of Agricultural Extension,* 23(1), 1-13.

Aiyegoro, O. A., Akinpelu, D. A., Igbinosa, E. O. & Ogunmwonyi, H. I. (2007). Effect of cassava effluent on the microbial population dynamic and physicochemical characteristic on soil community. Sci Focus, 12, 98-101.

Akpan, E. A. & Udoh, V. S. (2017). Evaluation of Cassava (Manihot Esculenta crantz) Genotype for Yield and Yield Component, Tuber Bulking, Early Maturity in Cross River Basin Flood Plains, Itu, Akwa Ibom State, Nigeria. Canadian Journal of Agriculture and Crops, 2(2), 68-73.

Akpan, J. F., Eyong, M. O. & Isong, I. A. (2017). The Impact of Long-term Cassava Mill Effluent Discharge on Soil pH and Microbial Characteristics in Cross River State. *Asian Journal of Soil Science and Plant Nutrition,* 2(1): 1-9.

Antonangelo, J. A., Culman, S. & Zhang, H. (2024). Comparative analysis and prediction of cation exchange capacity via summation: influence of biochar type and nutrient ratios. Front. Soil Sci., 4. https://doi.org/10.3389/fsoil.2024.1371777

Barnett, H. L. & Hunter, B. B. (1986). Illustrated Genera of Imperfect Fungi, 4th Edition. Macmillan Publishing Co., New York.

Bremner, J. M. (1996). Total nitrogen. In Methods of Soil Analysis: Part 3—Chemical Methods (pp. 1085-1121). Soil Science Society of America, Inc.

Cheesbrough, M. (2005). *District Laboratory Practice in Tropical Countries*. Part 2. Cambridge University Press.

Chinyere, G. C., Ojiako, F. O. & Chukwuma, M. O. (2013). Evaluation of the Proximate Composition and Functional Properties of Cassava (*Manihot esculenta Crantz*) Flour. *Journal of Food Science and Technology*, 50(4), 764-771.

Dubey, R. C. & Maheshwari, D. K. (1999). *Practical Microbiology*. S. Chand and Company Ltd.

Ebhoaye, J. E., Akoroda, M. O. & Ilori, C. O. (2004). Evaluation of Cassava (Manihot esculenta Crantz) Genotypes for Yield and Tuber Quality. *Journal of Root Crops*, 30(1), 17-24.

Edwin, N., Obasi, D. C. ., Offor, C. E. , Obasi, J. N. , Ugwu, O. P. C. , Aja, P. M., Ogbanshi, M. E. , Uraku, A. J., Alum, E. U & Ali, F. U. (2022). Impact of soil physicochemical properties on mineral composition of cassava samples from Ikwo LGA of Ebonyi State, Nigeria. *J. Chem. Soc. Nigeria*, 47(6),1202 – 1213.

Famuyini, J.& Sedara, A (2022). *Impact of Cassava Processing Mill Effluent on Physical and Chemical Properties of Soil in Akure,* Ondo State, Nigeria. Turkish Journal of Agricultural Engineering Research (TURKAGER), 3(2), 265-276. https://doi.org/10.46592/turkager.1102436

Fawole, O. B. & Oso, B. A. (2004). Influence of cassava effluent on microbial load and physico-chemical properties of a receiving stream. *African Journal of Biotechnology*, 3(10), 523-527.

Gee, G.W. &Or, D. (2002). Particle Size Analysis. In: Methods of Soil Analysis, Part 4, Physical Methods, Dane, J.H. and G.C. Topp (Eds.). ASA and SSSA, Madison, WI., pp: 255-293.

Holt, J. & Chancellor, T. C. B. (1994). Cassava in Amazonia - a review of the evidence for cassava being a major food source prior to contact. World Archaeology, 26(1), 121-135.

Igbinosa, E. O. & Igiehon, O. N. (2015). The Impact of Cassava Effluent on the Microbial and Physicochemical Characteristics on Soil Dynamics and Structure. *Jordan Journal of Biological Sciences,* 8(2), 108-112

Iyagba, A. B., Akpensuen, T. F. & Okorie, I. (2018). Evaluation of the Effects of

Climate Change on Cassava Production in Nigeria. *Journal of Environment and Earth Science,* 8(1), 34-42.

Kuo, S. (1996) Phosphorus. In: Sparks, D.L., Ed., Methods of Soil Analysis: Part 3, SSSA Book Series No. 5, SSSA and ASA, Madison, 869-919.

Nelson, O. W. & Sommers L. E. (1996). Total Carbon, Organic Carbon and Organic Matter. In O. L. Sparks (ed). Methods of Soil Analysis Part 3, Chemical Methods. Soil Science Society of America Book Series Number 5. American Society of Agronomy, Madison WIE, pp 961 – 1010.

Nwakaudu, M. S., Kucha, C. C. & Okoli, I. C. (2012). Proximate and mineral composition of cassava (Manihot esculenta Crantz) leaves and tubers. *Journal of Food Science and Technology,* 49(3), 528-533.

Nweke, R. N. & Onuoha, S. C. (2024). Effects of cassava processing effluents on the soil microbial population dynamics in selected communities in Abakaliki, Ebonyi State, Nigeria *Chem Search Journal,* 15(1): 27 – 38.

Obueh H.O. & Odesiri-Eruteyan, E. (2016). A Study on the Effects of Cassava Processing Wastes on the Soil Environment of a Local Cassava Mill. J Pollut Eff Cont 4: 177. doi: 10.4176/2375-4397.1000177

Ogboghodo, I.A., Oluwafemi, A. P. & Ekeh, S. M. (2006). Effects of polluting soil with cassava mill effluent on the bacteria and fungi populations of a soil cultivated with maize. *Environ Monit Assess*., 116(1-3):419-25. doi: 10.1007/s10661-006-7658-6. PMID: 16779605.

Oguntimehin, I., Oyeyemi, O. T. & Oladipo, O. (2020). Assessment of the impact of climate change on cassava (Manihot esculenta) production in Nigeria. *Journal of Agricultural and Environmental Sciences*, 9(2), 114-123.

Okafor, J. N. C. (2008). Chemical composition of cassava (Manihot esculenta Crantz) leaves and tubers. *Journal of Food Science and Technology*, 45(3), 261-265.

Okechi, J. J., Onyango, C. A. & Mwangi, M. (2011). Evaluation of Cassava (Manihot esculenta Crantz) Genotypes for Yield and Resistance to Cassava Mosaic Disease. *Journal of Agricultural Science,* 3(2), 132-138.

Olorunfemi, D.I., Emoefe, E. O. & Okieimem F. E. (2008). Effect of cassava processing effluent on seedling height, Biomass and chlorophyll content of some cereals. *Research Journal of Environmental Sciences*, 2(3):221–228.

Omonoma, V. F. & Akipelu, A. O. (2010). Evaluation of the nutritional and anti-nutritional composition of cassava (Manihot esculenta Crantz) leaves. *Journal of Food Science and Technology* 43(3), 297-283

Osakwe, S. A. (2012). Effect of Cassava Processing Mill Effluent on Physical and Chemical Properties of Soils in Abraka and Environs, Delta State, Nigeria. *Chemistry and Materials Research,* 2(7),27-39.

Oyewole, O. I., Ogunjobi, A. A. & Oladipo, O. O. (2017). Effect of Climate Change on Cassava Production in Nigeria. *Journal of Climate Change and Sustainability,* 1(1), 23-32.

Udo, E.J., Ibia, T. O., Ogunwale, J. A., Ano, A. O. & Esu, I. E. (2009). Manual of Soil, Plan and Water Analyses. Sibon Books Limited, Lagos, Nigeria, pp. 183