

Original Research Article

ASSESSING THE IMPACT OF LONG-TERM CASSAVA MILL EFFLUENT DISCHARGE ON SOIL pH AND MICROBIAL CHARACTERISTICS IN CROSS RIVER STATE

Abstract

Increasing level of cassava effluent discharge on agricultural soils has become a source of concern for environmentalists including soil scientists. Therefore, this study assesses the impact of such activities on soil pH and microbial characteristics. The result obtained showed that the soil samples collected after 25 m away from the point of effluent discharge were slightly acid to slightly alkaline in pH, while those at the point of effluent discharge up to 10 to 25 m away from the point of effluent discharge were acidic. This showed that cassava mill effluent discharge increases soil acidity which in turn tends to suppressed bacterial growth in the soil within the point of discharge. The control soil had the highest microbial count than impacted soils. The microbial species isolated included such bacteria as *Lactococcus lactis*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Micrococcus variance* and *staphylococcus aureus* while the fungal isolates include *Aspergillus niger*, *Fusarium spp*, *Penicillium spp*, *Mucor spp* and *Rhizopus spp*. The result further showed that in impacted soil *Bacillus subtilis* (27.78 %), and *Rhizopus sp* (28 %) had the highest frequency of occurrence for bacteria and fungi respectively while in the control soils *Lactococcus lactis* (26.67 %), and *Rhizopus sp* (27.27 %) and *Penicillium spp* (27.27 %) were the most dominant bacteria and fungus isolated across the different sampling distances. Hence, there should be an increasing awareness of the emergency created by cassava processing mills and management practices should be adopted to remediate the impacted soil.

Keywords: Bacteria, Cassava effluent, Fungi, Soil pH

Introduction

Cassava is an important food security crop in Nigeria. It produces the food that feed the populace and also provides the primary source of livelihood for the rural poor. It is seen to have a high poverty-reduction potential for Nigeria due to its low production cost [1] and [2]. Currently, Nigeria is the World largest producer of cassava accounting for 19 per cent of total world production and about one-third of the total national output of cassava comes from the Niger Delta region where many livelihoods depend on cassava as a main source of food and income [3]. This upsurge in the production and utilization of cassava in recent years has led to the

establishment of cassava milling engines in many production areas. The cassava production system in Cross River State and elsewhere in Nigeria is characterized by small-scale farmers that cultivates less than 2 hectares of land and is subsistent in nature, primarily cultivated for the traditional food market. However, any surplus cassava harvest in this production system is sold to local processors.

Raw cassava produce can be process into diverse traditional delicacies and industrial product which include; garri, fufu, starch, lafun, chips, pellets, cake, flour etc, some of which are fermented products [4] and [5]. However, 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 [6] in [7]. The processing of cassava has increased extensively in recent times and this processing has equally increased the environmental pollution associated with the disposal of the effluents. This is so because cassava processing traditionally generate a lot of waste (e.g water, hydrocyanic acid, peels and sieves from the pulp) from cassava mills which are usually discharged on land indiscriminately and this in turn affects soil and groundwater including biota (plant and micro-organism) [8] and[9] within the confinement where such activities are carried out.

Garri, starch and /or fufu production makes use of large volume of water which results in discharge of same amount as wastewater. The wastewater is discharge indiscriminately by most processor and allowed to accumulate on the soil, even near residential homes, producing offensive odours and unsightly scenarios [8] and [6]. This wastewater from the processing factory contains cellulose, carbohydrate, nitrogenous compounds, varying concentration of heavy metals and cyanoglycosides. Cyanogens and glycosides are easily hydrolyzed into hydrogen cyanide

which is toxic to soil, biota and aquatic animals, thus posing serious threat to humans and environment [10] , [11] and [12].

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 is carried out. Soils especially the first 0-20 cm depth otherwise known as the topsoil consists 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 to a serious imbalance in the microbial population, which in turn could result to 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 physico-chemical changes in the soil properties when the effluent are discharged on it [13] and [14]. This however, shows that cassava mill effluent discharge has the tendencies to alter soil properties causing changes in soil chemical, physical and microbial properties most especially pH, C/N ratio and bulk density, exchangeable cations and microbial loads [15], [16] and [7]. When cassava mill effluent is discharged into the soil, the pH is generally acidic but gradually increases to alkaline as biodegradation takes place [17] due to release of ammonia. The observed changes in soil pH affect soil microbial loads, which in turn affects plant nutrient availability [18], soil health and plant growth [19]. The increased soil alkalinity led to reduction in plant growth [20] and probably explains in part the high level of plant withering seen at cassava milling sites.

Most importantly, the cassava mills in the studied areas are mainly on small scale basis, owned and managed by individuals who have no basic knowledge of environmental protection. Though on small scale basis, there are many of them, which when put together, create negative impact on the environment. Interestingly, Nigeria government is currently working towards increased cassava

cultivation with harvest target of 150 million tons annually and the establishment of hundreds of cassava processing centers [21]. This means that there will be great increase in the effluent water generated. According to [22], “there is neither a specific method of disposal or of treatment of the cyanide-laden wastewater resulting from cassava processing in Nigeria nor any government policy guidelines”. Therefore, there is a need to assess the impact of cassava mill effluent on soil pH and microbial characteristics which are the key indicators of productive soils and thus calls for regulation in the discharge of the waste generated. The aim of this research was to assess the long-term impact of cassava mill effluent discharge on soil pH and microbial load in the surrounding soils.

Materials and methods

Description of the study Area

The study was conducted in two agricultural zones of Cross River State, viz; Central and Southern Agricultural Zone. Obubra and Odukpani were chosen to represent Central and Southern Agricultural Zone respectively, due to predominant of cassava milling plants. In each of the selected local government areas, investigation was done in mills that have received effluent for a minimum of ten years. In Odukpani local government area, Usung Odot, Ndon Nyam and Ikot Nyong were the three sampling areas whereas in Obubra local government area Wankade II, Ochon Town and Apiapom were the sampling areas. Obubra (longitude $6^{\circ} 5'$ and $8^{\circ} 20'$ E and latitude $5^{\circ} 41'$ and $6^{\circ} 10'11''$ N) and Odukpani (latitude $5^{\circ}25'N$ and longitude $8^{\circ} 0'E$) falls within the rainforest zone of Cross River State where the rainy season lasts for about 7-8 months with the dry months having less than 60 mm of rainfall. It has temperature with average daily maximum of $35^{\circ}C$. The rainy season has a short dry period called “August Break” or short dry season, which last between 2 to 4 weeks. The underlying geological material of Odukpani

consists of coastal plain sand, made up of unconsolidated sandy sediments underlain by massive deposit of limestone. The geological formation of Obubra area consists predominantly of basement complex formation of sedimentary rocks, sandstone, shale, basalt, siltstone and quartz, mica and schist. The Vegetation of the area is humid tropical rainforest. The area is used predominantly for horticultural and arable crop cultivation where crops like maize, watermelon, fluted pumpkin, cassava and yam are grown.

Samples Collection

Soil auger was used to collect soil samples from a depth of 0-20 cm from soil impacted with cassava effluent discharge in Wankade II, OchonTown and Apiapom in Obubra LGA and Usang Odot, Ndon Nyam and Ikot Nyong in Odukpani LGA. The soil samples from the cassava processing plant were collected at different distances: from the dump site, point of discharge, 10 m, 25 m, 50 m and 100 m away from the site using sterile plastic bags. The soil bulk samples from the 100 m distance served as control. All the samples were transported to the Laboratory for analysis. At each sampling distance, three samples were collected and pooled to give a composite sample for that particular sampling distance.

Sample preparations

The samples were air dried, crushed to fine particles and sieved using 2mm sieve and then stored in fresh clean polyethylene bags in the refrigerator between 7-14 days to maintain the stability of the samples without significant alteration in their biological properties.

Determination of Soil pH

Soil pH was determined using a 1:2.5 (w/v) soil-water ratio by pH-meter with a glass electrode pH meter [23]

130 **Microbial analysis**

131 **Enumeration of total heterotrophic bacteria and fungi**

132 The total aerobic bacterial and fungal counts were carried out using pour plate technique as
133 described by [24], after ten-fold serial dilution. The media of choice were Oxoid Nutrient agar,
134 Agar-Agar extract and Saboroud Dextrose agar, prepared according to the manufacturer's
135 instruction.

136 **Characterization and identification of microbial isolates**

137 The bacteria isolates were identified by biochemical test (gram reaction, motility, indole,
138 catalase, coagulase, oxidase, urease and citrate). The resultant characteristics were compared
139 with those of known taxa using the keys provided in the Bergey's Manual of Determinative
140 Bacteriology by [25] and the scheme of [26]. The cultural characteristics of the bacteria isolated
141 were compared with the culture characteristics presented by [27]. Fungal isolates were examined
142 macroscopically and microscopically using the needle mounts technique. Their identification
143 was performed according to the scheme of [28] and [29].

144

145 **Results**

146 **Lateral distribution of Soil pH**

147 The lateral distribution of soil pH in the studied soil is presented in Table 1. In Obubra local
148 government area, the lowest soil pH value of 4.4 was observed at the point of discharge, whereas
149 the highest soil pH value of 5.7 was observed at 50 and 100 m away from the point of effluent
150 discharge. Similarly, in Odukpani local government area, the lowest soil pH value of 4.3 was
151 observed at the point of discharge, whereas the highest soil pH value of 7.4 was observed at 25 m
152 away from the point of effluent discharge. The soils at the point of discharge consistently had
153 lower value of soil pH and tend to increase as distance increases. This means that the further the

sampling point away from the cassava effluent discharge points, the higher the value of soil pH. This is consistent with some other reports [6], [16] and [30]. Although in some studied location, the observed soil pH value at 100 m away from the point of discharge were lower than those of 25 and 50 m point. This may be attributed to the fact that the effluent discharge on reaching these points, the concentration tend to be lower as compared to those around the point of discharge and 10 m away from discharge point, and this tends to encouraged more microbial degradation at these points with the resultant release of ammonia which leads to consequent increase in soil pH. Nevertheless, studies that have been done on the effect of cassava mill effluent discharge on soil physico-chemical properties has always showed a negative impacts of the discharge on soil properties. For example studies by [13] and [14] showed that there was an increase in soil acidity and organic matter content and decrease in calcium, nitrogen and magnesium contents of the soil when cassava effluent was discharged on it. Generally, the soil pH of the impacted soils were lower (i.e more acidic) than those of the unimpacted soil. This is no doubt due to the presence of hydrogen cyanide present in the effluent [14].

Lateral distribution of microbial load

In Table 2 is presented the microbial population at various distances from the mill. The result showed that sample collected at the point of effluent discharge and 10 m away from the point of effluent discharge recorded the least average bacterial count value of 8.0×10^5 cfu/g (Wankade soil) and 8.0×10^5 cfu/g cfu/g (Ochon Town), and the highest average fungal count value of 5.0×10^3 cfu/g (Ndon Nyam and Ikot Nyong soil) and 5.0×10^3 cfu/g (Usang Odot) compared to samples collected at other distances away from the point of effluent discharge. The higher fungal count in impacted soil than control soil could be attributed to the more robust nature of fungi which enables them to withstand the more acidic environment of the soil than bacteria [31].

178 Table 1: Effect of cassava effluent on soil pH along a gradient from the point of discharge

Distance away from the mill (meters)	pH
Obubra Local Government Area	
Wankade II	
Point of discharge	4.7
10 meters away	5.0
25 meters away	5.3
50 meters away	5.6
100 meters away	5.7
OchonTown	
Point of discharge	4.9
10 meters away	4.9
25 meters away	5.1
50 meters away	5.7
100 meters away	5.0
Apiapom	
Point of discharge	4.4
10 meters away	4.8
25 meters away	5.4
50 meters away	5.6
100 meters away	5.7
Odukpani Local Government Area	
Usang Odot	
Point of discharge	4.3
10 meters away	4.9
25 meters away	7.4
50 meters away	6.7
100 meters away	5.4
Ndon Nyam	
Point of discharge	4.6
10 meters away	4.8
25 meters away	6.4
50 meters away	5.6
100 meters away	5.6
Ikot Nyong	
Point of discharge	4.5
10 meters away	4.7
25 meters away	6.1
50 meters away	5.8
100 meters away	5.6

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181 The populations of the different bacterial groups were lower in the impacted soil than the control.

182 The high content of cynogenic glucoside, example, linamarin, in cassava mill effluent may have

adversely affected the microbial load [16]. Bacterial counts were generally higher than fungal count. In general, the microbial load of the impacted soil was lower than the control sample. The relatively low count of impacted soil could be attributed to the effluent making the soil acidic due to the presence of cyanide. The presence of the cyanide in the soil could lead to inhibition of bacteria growth [11]. The occurrence of isolated microorganisms is presented in Table 3. The results revealed the isolation of such bacteria as *Lactococcus lactis*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Micrococcus varians* and *staphylococcus aureus* while the fungal isolates include *Aspergillus niger*, *Fusarium spp*, *Penicillium spp*, *Mucor spp* and *Rhizopus spp*. The microorganisms isolated from the effluent impacted soil were in line with the previous works of [32] and [33] who isolated similar organisms. Bacterial and fungal species were encountered in both impacted and control soils in course of this study, but their occurrences and levels of predominance were different. In impacted soil *Bacillus subtilis* (27.78 %) and *Rhizopus spp* (28 %) were the dominant bacteria and fungi isolated while in the control soils *Lactococcus lactis spp* (26.67 %) and *Rhizopus spp* (27.27 %) and *Penicillium spp* (27.27 %) were the most dominant bacteria and fungus across the different sampling distances.

213 Table 2: Effect of cassava effluent on microbial load of soil (CFU/g) along a gradient from the
214 point of discharge

Distance away from the mill (meters)	Total Aerobic bacterial count (cfu/g) x10 ⁵	Total fungal count (cfu/g) x10 ³
Obubra Local Government Area		
Wankade II		
Point of discharge	8.0	4
10 meters away	8.5	4
25 meters away	8.6	3
50 meters away	15	2
100 meters away	17	2
OchonTown		
Point of discharge	8.0	3
10 meters away	8.0	3
25 meters away	12.0	2
50 meters away	10.5	2
100 meters away	15	2
Apiapom		
Point of discharge	11.5	2
10 meters away	14.0	3
25 meters away	16.0	1
50 meters away	15	2
100 meters away	17	1
Odukpani Local Government Area		
Usang Odot		
Point of discharge	10	3
10 meters away	10	5
25 meters away	14	5
50 meters away	14	4
100 meters away	11	3
Ndon Nyam		
Point of discharge	9	5
10 meters away	11	5
25 meters away	12	4
50 meters away	16	3
100 meters away	14	3
Ikot Nyong		
Point of discharge	10	5
10 meters away	11	3
25 meters away	14	3
50 meters away	17	2
100 meters away	16	4

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218 **Table 3: The microorganisms isolated from the impacted and control soil samples and their**
 219 **percentage occurrence**

Organisms isolated	Occurrence of isolates					Frequency of occurrence	
	Point of discharge	10	25	50	100	Impacted soils	Control soil
Bacterial							
<i>Lactococcus lactis</i>	-	+	+	+	+	4(22.22)	8(26.67)
<i>Bacillus subtilis</i>	-	+	+	+	+	5(27.78)	6(20)
<i>Pseudomonas aeruginosa</i>	-	-	+	+	+	3(16.67)	5(16.67)
<i>Micrococcus varians</i>	-	-	+	+	+	2(11.11)	4(13.33)
<i>Staphylococcus aureus</i>	-	+	+	+	+	4(22.22)	7(23.33)
Fungal							
<i>Aspergillus niger</i>	+	+	-	+	+	3(12)	1(9.09)
<i>Penicillium spp</i>	+	+	-	-	+	4(16)	3(27.27)
<i>Fusarium spp</i>	+	+	+	-	+	6(24)	2(18.18)
<i>Mucor spp</i>	+	+	-	-	+	5(20)	2(18.18)
<i>Rhizopus spp</i>	+	+	+	+	+	7(28)	3(27.27)

220 + = microbes is present; - = microbes is absent; values in parenthesis are percent occurrence
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223 Discussion of results

224 The soil pH at the point of discharge and 10 m away from discharge point were highly
 225 acidic. This can be detrimental to agricultural activities in where such cassava mills are located,
 226 as soil pH determines the availability of nutrients and the potency of toxic substances as well as
 227 the physical properties of the soil [34]. The soil pH values of the soils around the point of effluent
 228 discharge indicate a generally high tendency for high availability of the metals; hence, this
 229 increases the risk of heavy metals uptake by crops. It has also been reported by [35] in [36] that
 230 soil acidity influences many chemical and biological characteristics of soil, including availability
 231 of nutrients and toxicity of metals which can also affect microbial communities in many ways.
 232 Acidic soils can significantly reduce nodule numbers, nodulation and nodule function, and N-
 233 fixing capabilities within the roots of legumes [37]. This may result in reduced plant vigor and
 234 productivity, as well as significant crop loss. Beneficial soil microbes and plants prefer a near-

neutral pH range of 6 to 7, so increased soil acidity is often accompanied by shifts in the types of microbes in soils and their activities [36]. This means significant changes in the rate of decomposition which can lead to immobilization of basic nutrients and decreased nutrient availability to plant. The acidic nature of soils at point of effluent discharge up to 10 to 25 m away from the effluent discharge means reduced microbial function and this can adversely affect soil health and productivity. Soil fungi are favoured by a low soil pH, implying that at lower soil pH the soil is much more fungi-dominated [38]. This may allow the invasion of fungal root pathogens and also change the way organic residues are decomposed, and this may in turn immobilized soil carbon and plant nutrients slowing turnover and nutrient release [39].

The result of microbial load analyzed showed that the bioloads of all the bacteria groups increased with distance away from the point of discharge (see Table 2). This observation suggests an adverse growth conditions towards the discharge point. However, most values obtained at 50 m away from the discharge point were higher than those from control. Fungal counts were higher in impacted soils than control soils. The relative increase in the fungal growth in the impacted soil may be due to the acidic pH of the soil which in most cases where as low as 4.3 (Table 1). On the contrary, the relative low fungal diversity, observed in the control soil, could be attributed to the near neutral pH in most location. The low pH of the soil could explain the presence of cyanogenic glycosides in the cassava effluent impacted soil [33]. Microbes in soil are important to healthy soil processes and good soil quality. [36], aptly stated that many aspects of most nutrient cycles are controlled by soil microbes, in that without microbes, organic matter decomposition simply would not occur, legumes would not be able to fix nitrogen, and ammonia would not be converted to plant-available nitrate.

258 **Conclusion**

259 The result obtained from this study has indicated adverse environmental effects of cassava mill effluents
 260 discharge on soil pH and microbial loads. Analysis results showed that soil pH close to the point of
 261 effluent discharge was highly acidic and the microbial activities especially bacterial around these points were
 262 very low. This suggests that cyanide and low soil pH causes soil toxicity and impedes microbial
 263 activity from the impacted soils. The result further showed that soil pH-driven changes to soil
 264 chemistry and biology, can have a major influence on microbial population and function,
 265 consequently altering nutrient cycling, organic matter degradation, crop productivity and overall
 266 ecosystem services. It is very clear from this investigation that any imbalance in the microbes in
 267 soils can lead to reduced soil microbial health which can impact on general crop productivity.
 268 Hence, understanding more precisely the response of beneficial soil microbial populations to
 269 acidification caused by cassava mill effluent discharge and its resultant effect on soil health will
 270 provide valuable insights to sustainable agriculture and healthy environmental management.

271 **Recommendations**

- 272 i) There should be rehabilitation of the impacted soils if it will be used for agricultural purposes
 273 as the factors important in soil health are negatively affected;
- 274 ii) Regulations to control the disposal of wastes generated from cassava mills should be
 275 introduced, as most cassava mills are sited near residential areas;
- 276 iii) Hazard analysis and critical control point measures should be developed for cassava
 277 processor; and
- 278 iv) There should be an increasing awareness of the emergency created by cassava
 279 processing mills.

v) It is also recommended that the pH of the effluent should be to alter to near neutral before discharging them on soil.

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