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A Study on the Effects of Cassava Processing Wastes on the Soil Environment of a Local Cassava Mill

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Abstract

This study examines the effects of cassava processing wastes on the soil environment of a local cassava mill in Ekiadolor, Ovia North East Local Government Area of Edo State, Nigeria. Microbial, physicochemical and mineral compositions of fresh cassava effluent, cassava effluent from waste pit, soil around the cassava mill (soil 1) and soil samples 100 m away from the mill (the control, soil 2) were determined. Soil 2 had the highest microbial count of 3.52 × 10^5 cfu/ml. The microbial species isolated included *Klebsiella aerogenes*, *Bacillus subtilis*, *Lactobacillus plantarum*, *Staphylococcus aureus*, *Lactobacillus delbrueckii*, *Fusarium solani*, *Aspergillus niger* and *Saccharomyces cerevisiae*. The occurrence of the isolated microorganisms was lowest in soil 1 with 37.5%. Fresh cassava effluent was the most acidic with pH 3.2 and cassava effluent from waste pit had the highest cyanide content of 53.52 mg/l. The mineral contents (Ca, Mg, Na and K) of the fresh cassava effluent, effluent from waste pit and soil 1 were significantly lower ($p<0.05$) than the control. The heavy metals (Fe, Zn, Mn, Al, Pb and Cu) were significantly higher in soil 1 when compared with soil 2. Nitrate and phosphate contents were high in all the samples except the control. The continuous disposal of the cassava processing wastes in the soil environment around the mill and into a waste pit has reduced the soil quality leading to environmental degradation.

Keywords: Cassava mill; Cassava processing wastes; Environment; Soil

Introduction

Cassava is the third major source of carbohydrate in the world with diverse uses depending on the community serving as food security for the many millions of people in developing world [1]. Nigeria is the largest producer of cassava with approximately 45 million tonnes in 2009, which was almost 19% of production in the world [2]. All communities in Nigeria depend so much on cassava because of its wide usage when processed into garri, tapioca, akpu, fufu and starch. Cassava is normally processed before consumption as a means of detoxification, preservation and modification [3] due to the presence of toxic cyanogenic glucosides in unfermented roots and leaves [4].

Cassava processing generates solid and liquid residues that are hazardous in the environment [5]. The two important biological wastes that may cause damage to the environment are derived during cassava processing and they are the cassava peels and the liquid effluent squeezed out of the fermented parenchyma mash [6]. The peels are usually discharged on land or water as wastes and allowed to rot in the open thus resulting in health and environmental hazards. The cassava effluent contains a heavy load of microorganisms capable of hydrolyzing the glucosides. The pollutant potential of an effluent is measured by the amount of oxygen needed to oxidize the organic matter, the Chemical Oxygen Demand (COD) and the amount of oxygen necessary to stabilize the organic matter by microorganisms and enzymes, the Biochemical Oxygen Demand (BOD) [7].

Liquid effluents contain many nutrients, suitable to increase soil fertility as opposed to the water carried by them, which is pollutant to the environment [8]. Compounds that are generally toxic to living organisms will also at toxic concentrations prevent germination as well as inhibit growth. Continuous discharge of the effluent into the soil for a long period of time leads to the extinction of some bacteria and fungi types that were originally available in the soil. When cassava effluent is released directly into streams and rivers, it would cause rapid growth of bacteria, resulting in oxygen depletion and death of fish and other aquatic life [9].

In Southern Nigeria, cassava milling is one of the major industries and the mills are usually sited around where the effluent is capable of causing pollution to arable land, fresh water and soil around the mill. The continuous increase in supply and demand for cassava in developing countries has accentuated the negative impact cassava production and processing has on the environment and biodiversity. The main objective of this study is to evaluate the effects of cassava processing wastes on the environment and proffer solutions to their indiscriminate disposal.

Materials and Methods

Sample collection

Fresh cassava effluent from a cassava mill in Ekiadolor, Ovia North East Local Government Area of Edo State, Nigeria (Lat 6°29’N, long 5°35’E) was collected directly into sterile 150 centiliter plastic bottles. Cassava effluent from a waste pit behind the cassava mill was collected into sterile 1 liter plastic bottle. Soil around the cassava mill (Soil 1) and the control soil sample (Soil 2); 100 m away from the cassava mill were collected aseptically into black polythene bags. All samples were taken to the laboratory for analyses.

Physicochemical analyses

Physicochemical analyses were carried out. The pH was measured

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using a digital HANNA Combo pH meter. The meter was introduced into the sample and measurement was taken to get a stable reading. The electrode was then rinsed with sterile water before another measurement was taken [10]. Cyanide content was determined by the alkaline titration method [11], Protein content was by the Micro-Kjeldahl method [12], carbohydrate was determined colorimetrically by the anthrone method [13] and the Total Dissolved Solid (TDS) was determined using the gravimetric method by evaporation in an oven at 200°C for 2 hrs [14]. The COD, BOD, nitrate and phosphate contents were determined by standard methods of APHA [14]. The Ca, Mg, Fe, Zn, Mn, Al, Pb and Cu contents were determined using the AAS (Atomic Absorption Spectrometer) by the procedure of AOAC [10]. Na and K contents were determined by flame photometer [10].

Microbiological analyses

The bacterial and fungal counts of the samples were determined using pour plate techniques [15]. Ten ml of the effluent and 10 g of soils 1 and 2 were inoculated each into 90 ml of sterile water to give a 10^{-1} dilution. Serial dilutions from the suspensions were prepared to a range of 10^{-6}. From these dilutions, 1 ml was aseptically plated out for total viable counts of bacteria on Nutrient Agar (Lab M, UK) and total fungal counts on Potato Dextrose Agar (Lab M, UK) supplemented with 10% lactic acid and 0.5% chloramphenicol [16]. The colonies were observed and counted and expressed as colony forming units (cfu/ml). Representatives of the different purified colonies were subjected to various cultural, morphological and biochemical analyses [17]. Identification of the bacterial isolates was based on Bergey's Manual of Determinative Bacteriology [18] and fungal isolates was by wet mount method of Yarrow [19].

Statistical analyses

The data collected were analyzed using one way analysis of variance (ANOVA) and the significant means separated by Duncan's Multiple Range tests [20].

Results

In Table 1 is presented the microbial population in the different samples. The bacterial and fungal counts were highest in soil 2 ($3.52 \times 10^5 \pm 2.03$ cfu/ml and $2.90 \times 10^5 \pm 0.05$ cfu/ml) and lowest in soil 1 ($1.28 \times 10^5 \pm 0.05$ cfu/ml and $9.20 \times 10^4 \pm 0.01$ cfu/ml) respectively. The occurrence of isolated microorganisms is presented in Table 2. The isolated microorganisms included *Klebsiella aerogenes*, *Bacillus subtilis*, *Lactobacillus plantarum*, *L. delbruekii*, *Staphylococcus aureus*, *Fusarium solani*, *Aspergillus niger* and *Saccharomyces cerevisiae*.

Table 3 showed the physicochemical composition of the samples. The pH values were between 3.2 and 6.8. The cassava effluent sample was the most acidic with pH 3.2. The cyanide content was highest in the cassava effluent from waste pit (53.52 ± 0.03 mg/l). The BOD and COD values in the cassava effluent and effluent from waste pit were 6.45 ± 0.54 mg/l and 1480.4 ± 9.5 mg/l and 10.82 ± 0.03 mg/l and 841.0 ± 3.4 mg/l respectively. The TDS concentration ranged from 97 ± 2.0 mg/l to 265 ± 4.0 mg/l. The carbohydrate content by difference in percentage was highest in the cassava effluent (73.24 ± 1.50%) and lowest in the soil 2 sample (22.40 ± 1.10%). Nitrate and phosphate contents were lowest in the soil 2 (1.72 ± 0.02 mg/l and 0.21 ± 0.01 mg/l) and highest in the effluent from waste pit (1.95 ± 0.12 mg/l) and the cassava effluent (0.45 ± 0.32 mg/l) respectively. The crude protein concentration was highest in the soil 2 (0.53 ± 0.03%).

Microbial Counts (cfu/ml)	Cassava Effluent	Effluent from waste pit	Soil 1	Soil 2
Bacterial counts	$1.75 \times 10^5 \pm 0.04^b$	$1.63 \times 10^5 \pm 0.01^b$	$1.28 \times 10^5 \pm 0.05^b$	$3.52 \times 10^5 \pm 0.03^a$
Fungal counts	$1.26 \times 10^5 \pm 0.06^a$	$1.35 \times 10^5 \pm 0.02^a$	$9.20 \times 10^4 \pm 0.01^b$	$2.96 \times 10^5 \pm 0.05^c$

Table 1: Microbial population (cfu/ml) of the samples.

Isolated microorganisms	Occurrence in samples			
	Cassava effluent	Effluent from waste pit	Soil 1	Soil 2
Klebsiella aerogenes	+	+	-	+
Bacillus subtilis	+	+	-	+
Lactobacillus plantarum	+	+	+	+
L. delbruekii	+	+	-	+
Staphylococcus aureus	-	+	+	+
Fusarium solani	-	-	+	+
Aspergillus niger	-	-	-	+
Saccharomyces cerevisiae	+	+	-	+
% occurrence	62.5	75	37.5	100

+=present, -=absent

Table 2: Occurrence of isolated microorganisms.

The mineral composition of the samples from this study showed that soil 2 had the highest concentrations for Ca, Mg, Na and K and lowest concentrations for Fe, Zn, Mn, Al, Pb and Cu (Table 4). The heavy metal concentrations were significantly lower in soil 2 than the other samples.

Discussion

The microbial population of soil 2 was higher than the other samples. The relatively lower microbial population could be attributed to the acidic nature of the effluent due to the presence of cyanide. Cyanide in the soil and fermented cassava could lead to the inhibition of microbial growth [21]. Disposal of cassava wastes from processing activities in mills lead to the release of a wide variety of microorganisms. These organisms may release toxins in the effluent which can be harmful [22]. Only those that can withstand the high acidic condition of the processing wastes will dominate, thus the lower population of the fungal species. The absence of the acidic effluent in soil 2 attributes for the 100% occurrence of the isolated organisms. *Lactobacillus plantarum* was the most prevalent microorganism due to its ability to maintain a pH gradient between the inside and outside of its cell in the presence of large amounts of acetate and lactate [23].

The pH of the cassava effluent was very acidic due to the high cyanide content [24]. Effluent from cassava processing plants are therefore regarded as harmful and should not be allowed to spread over farmlands [22]. The soil pH determines the availability of nutrients and the potency of toxic substances as well as the physical properties of the soil [25]. Ubalua [26] reported that cassava peels contained a higher level of cyanogenic glucosides than the pulp; hence the peels are typically dumped into the environment and allowed to decompose naturally. The cassava effluent from the waste pit had the highest cyanide concentration as a result of the dumping of the peels and effluent into the pit. Okafor [27] reported a large concentration of cyanide in soil receiving cassava processing effluents though soil 1, from this study had concentration of cyanide lower than the detrimental value of 30 mgHCN/kg [26].

The BOD and COD values from this study exceeded the [28] levels of 6 mg/l and 10 mg/l respectively for drinking water <4 mg/l and <500 mg/l for effluents as a threat to human health [29]. High

Parameter	Unit	Cassava Effluent	Effluent from waste pit	Soil 1	Soil 2
pH		3.2 ± 0.10[b]	3.9 ± 0.10[a]	4.2 ± 0.25[a]	6.8 ± 0.34[c]
Cyanide	mg/l	46.75 ± 0.01[c]	53.52 ± 0.03[a]	11.76 ± 0.01[a]	ND
BOD	mg/l	6.45 ± 0.54[b]	10.82 ± 0.03[b]	NA	NA
COD	mg/l	1480.4 ± 9.5[a]	841.0 ± 3.4[b]	NA	NA
TDS	mg/l	182 ± 1.0[c]	265 ± 4.0[a]	102 ± 3.0[a]	92 ± 2.0[b]
Carbohydrate	%	73.24 ± 1.50[a]	68.30 ± 1.36[a]	63.30 ± 1.36[a]	22.40 ± 1.10[b]
Nitrate	mg/l	1.83 ± 0.01[a]	1.95 ± 0.12[a]	1.84 ± 0.10[a]	1.72 ± 0.02[a]
Phosphate	mg/l	0.45 ± 0.32[a]	0.26 ± 0.45[b]	0.32 ± 0.02[a]	0.21 ± 0.01[b]
Protein	%	0.18 ± 0.10[c]	0.31 ± 0.03[a]	0.28 ± 0.05[a]	0.53 ± 0.03[b]

Values are means ± standard deviation (n=3). Means on the same row between samples with same superscripts are not significantly different (p>0.05). ND=Not detected; NA=Not applicable.

Table 3: Physicochemical composition of the samples.

Parameter	Unit	Cassava Effluent	Effluent from waste pit	Soil 1	Soil 2
Calcium (Ca)	mg/l	18.41 ± 2.42[b]	14.24 ± 1.00[a]	25.31 ± 0.09[b]	28.10 ± 0.01[c]
Magnesium (Mg)	mg/l	17.68 ± 3.10[c]	15.10 ± 0.05[b]	23.71 ± 0.50[a]	42.40 ± 0.03[a]
Sodium (Na)	mg/l	16.42 ± 0.03[a]	14.00 ± 0.10[c]	32.38 ± 2.00[a]	56.10 ± 0.05[b]
Potassium (K)	mg/l	15.92 ± 0.72[c]	10.26 ± 0.01[a]	15.98 ± 0.04[c]	31.34 ± 0.30[b]
Iron (Fe)	mg/l	72.65 ± 1.32[b]	98.01 ± 5.00[b]	25.60 ± 0.01[b]	0.10 ± 0.01[a]
Zinc (Zn)	mg/l	25.11 ± 0.35[c]	37.42 ± 2.00[c]	11.35 ± 0.06[b]	1.24 ± 0.50[a]
Manganese (Mn)	mg/l	3.30 ± 0.20[a]	5.20 ± 0.01[a]	2.10 ± 0.02[c]	0.92 ± 0.02[b]
Aluminium (Al)	mg/l	1.12 ± 0.05[c]	3.00 ± 0.30[b]	0.85 ± 0.01[c]	0.04 ± 0.01[a]
Lead (Pb)	mg/l	0.72 ± 0.06[a]	0.98 ± 0.05[a]	0.52 ± 0.01[a]	0.01 ± 0.00[b]
Copper (Cu)	mg/l	3.26 ± 0.25[c]	3.58 ± 0.04[c]	1.63 ± 0.02[a]	0.01 ± 0.00[b]

Values are means ± standard deviation (n=3). Means on the same row between samples with same superscripts are not significantly different (p>0.05).

Table 4: Mineral composition of the samples.

BOD constituted risks to fauna, flora and surface or underground water [8]. The high BOD and COD levels from this study might be attributed to the presence of high organic matter in the effluent [30]. The organic matter is broken down by bacteria which require oxygen for decomposition process, thus increasing the levels of BOD and COD. TDS is a measurement of inorganic salts, organic matter and other dissolved materials in water [31]. TDS if high causes toxicity through changes in ionic composition of the water and individual ions. The TDS levels from this study were within the desirable safe level of <500 mg/l [28]. The nitrate and phosphate levels were higher in the other samples than in the soil 2 sample. High nitrate levels have been associated with increased aeration [32] and increased concentration of ammonia. But altered pH in effluent soils has significantly higher nitrate and phosphate contents due to the fact that cellulose debris of the effluent enhanced organic matter decomposition [33]. This is in agreement with this study.

The mineral contents (Ca, Mg, Na and K) were significantly lower in the soil 1 than in soil 2 sample due to high content of hydrogen cyanide present in the contaminated soil [24]. The hydrogen cyanide dissolves in the effluent and remains in solution; when it enters the soil, part of the cyanogenic glycosides remain unconverted by microorganisms because of the few enzymes present in the cassava fibre which are not enough for complete conversion. This is detrimental to soil health and reduces quality of the soil and can result in the decrease of soil pH (increased acidity), magnesium, potassium, calcium and sodium while cyanide content, conductivity, phosphate, nitrate and sulphate were on the increase [22]. Long-term and continued use of effluent water may lead to changes in soil chemical and physical properties [34]. Heavy metals were higher in the effluent contaminated samples than the soil 2 sample. The higher level of the heavy metals in the effluent from waste pit was due to influxes of the effluent into the pit. This has deleterious effect on the environment. Heavy metals affect the growth, morphology and metabolism of microorganisms in soil through functional disturbance, protein denaturation or the destruction of the integrity of cell membranes [35]. Soils receiving cassava mill effluent have higher level of heavy metals with iron having the highest concentration [25]. This is in agreement with the report of this study that reported an increase in heavy metal content in the order Fe>Zn>Mn>Cu>Al>Pb for the cassava effluent, effluent from waste pit and soil 1 samples.

Conclusion

The continuous disposal of cassava processing wastes into the soil environment of the cassava mill brought about changes in the microbiological, mineral and physicochemical compositions of the soil environment around the mill. Most of the cassava millers in Ekiadolor are not educated and are not aware of the health and environmental effects of these wastes. Education about ways of detoxifying the wastes and proper disposal methods is therefore necessary.

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