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CONVERSION OF AGRO-WASTES INTO BIO-FERTILIZER BY ANAEROBIC DIGESTION FOR SOIL FERTILITY ENHANCEMENT

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ABSTRACT

There is a continuous demand for bio-fertilizer to improve the soil fertility and increase food production. Wastes were collected from eateries, food canteens, domestic houses and agricultural outlets. Five experimental set-ups were made using different combinations of digested wastes as follows: pig waste (Pw), cassava wastes (Cw), food wastes (Fw); pig waste + cassava waste (Pw+Cw), pig waste + Food wastes (Pw+Fw). The slurry of each category of bio-product were prepared by addition of appropriate volume of water, incubated for 70days with intermittent agitation at regular intervals in the digester. The principal bacteria which took the most active role in the bioconversion process were identified to *P. aeruginosa* and *Bacillus* spp. Comparative evaluation of each of the digested category of slurry combinations showed variations in their nitrogen content as follows: Pw(1.70± 0.03 mg/100g), Cw (0.61±0.02mg/100g), Fw (1.96±0.03mg/100g), Pw+Cw (1.20±0.01mg/100g), Pw+Fw (2.10± 0.02mg/100g). Pw+Fw showed highest K, P and Mg concentrations as 66.72± 2.36 mg/100g, 143.36± 2.36 mg/100g and 53.34±2.36 mg/100g respectively.The elemental composition in the increasing order in each of the slurry waste as follows: Cw<Fw< Pw <Pw+Cw<Pw+Fw There were shifts in the pH which could be due to metabolic activities and microbial interaction between the soil, other its component and added digested waste. The best performance in mineral content and plant growth noticed in Pw+Fw could be due to the nearness to neutrality of its pH.

Keywords: wastes, anaerobic, bio-fertilizer, soil fertility.

1. INTRODUCTION

Bio-fertilizers, being an essential component of organic farming are the preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic micro-organisms used for application to seed, soil or composting areas with the objective of increasing number of such micro-organisms and accelerate those microbial processes which augment the availability of nutrients that can be easily assimilated by plants. In Nigeria today, there is abundance of organic wastes which causes environmental pollution. Among such wastes are those from livestock farms such as pig, cattle, sheep and poultry waste (Oluyege *et al*., 2006). Instead of these wastes to continue to causes distress and threat for the environment, it is important that converting them into useful product such as bio-fertilizer would be of a great advantage. As it is generally known that the nature and the characteristics of nutrient release of chemical fertilizer, organic fertilizer, and bio-fertilizer are different, and each type of fertilizer has its advantages and disadvantages with regards to crop growth and soil fertility (Chen, 2006). Anaerobic digestion reduces the biological oxygen demand (BOD) and chemical oxygen demand (COD) of effluents and therefore decreases the potential dangers.

Anaerobic digestion offers a distinct advantage over aerobic processes in terms of pollution control as it does not require expensive oxygenation. Many materials treated by anaerobic digestion may contain certain organisms potentially pathogenic for plants, animals and man. Bacteria such as *Salmonella*, *Brucella and Clostridia* spp and parasites including tapeworm are potentially present in the untreated wastes. Raw sludge spread on land may introduce pathogens causing infection in farm animals or crops, run-off into water courses may result in human exposure. The anaerobic digestion process has some advantages over aerobic process due to a low energy requirement for operation and a low biomass production (Wang *et al*., 1999; Angenent *et al*., 2004), and it is considered a viable technology in the competent treatment of organic waste and the simultaneous production of a renewable energy.

The anaerobic digestion of organic waste is also an environmentally useful technology. This research work focus is to digest food wastes and some other agro wastes anaerobically under a controlled condition for bio-converting the waste into bio-fertilizer with applicability in soil improvement and sustenance, plant growth and development.

2. MATERIALS AND METHODS

2.1 Collection of Waste Materials for Digestion

Food wastes were collected from eateries, food canteens and domestic houses in Ogbomoso metropolis. Pig wastes were collected from the Teaching and Research of farm of LadokeAkintola University of Technology (LAUTECH), Ogbomoso. Wood ash was obtained by combusting dried branch of *Bauhiniamonandria* plant. Other salts such as Calcium carbonate ($CaCO_3$) and Magnesium sulphate ($MgSO_4$) were also purchased. The wastes were sterilized to kill any available microbial pathogens therein.

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2.2 Preparation of Slurry for Digestion

Each of the waste types collected were mixed together, digested anaerobically in a digester for 70 days. Sterile distilled water was added at interval, with intermittent stirring until digestion was fully achieved. The waste was designated as follows: Pig waste (Pw); Cassava waste (Cw); Food waste (Fw)*;* Pig and cassava waste (Pw+Cw); Pig and food waste (Pw+Fw).

2.3 Analyzing the Microbial Community of Digestate

The digestate was analyzed for its microbial community pre- and post- application.

2.4 Analyzing the Proximate Contents of Digestate

Proximate analysis was performed on the digestate to determine contents.

2.5 Analyzing the Elemental Composition of the Digestate

The elemental composition of the digestate was determined to know its nutritional contents using Atomic Absorption Spectroscopy (AAS).

2.6 Collection of Soil Samples

Infertile soil sample was collected from LAUTECH, Botanical garden using sterile hand-trowel which was then treated/ mixed thoroughly with each of the digestate produced.

2.7 Experimental Set-Ups

The experiment was set-up into five (5) groups according to each of the available digestate produced with soil sample without digestate as control. Treated Cowpea and maize seeds were purchased and planted onto each of the soil samples.

Each of the soil sample was placed in a screen house and monitored daily for growth. The pH and temperature was monitored daily. After germination, daily measurements of the shoots were carried out. After 14 days of observation and measurement of the growth, the seedlings were uprooted after which measurement of the shoot and roots were done separately.

3. RESULTS AND DISCUSIONS

The most important constraint limiting crop yield in developing nations such as Nigeria and especially among resource-poor farmers, is soil infertility. This research focused on bioconversion of wastes which actually are environmental pollutants into useful end product such as bio-fertilizer as an alternative to chemical forms which later pose threat to soil and its properties. In Nigeria, a lot of wastes are generated daily from different sources such as domestic, food canteens, agricultural outlets and eateries. All these were gathered in a sterile clean bag for anaerobic conversion processes.

Such has also been reported in Singapore wherein total food waste was collected from food processing companies, restaurants, food courts, markets and household (Ministry of Environment, 2002); although in their own report, the wastes were treated aerobically (Olena, *et al.,* 2005). The wastes were converted anaerobically by composting which has been reported to convert waste into a hygienic, humus-rich, relatively stable product that conditions soils and nourishes plants (Mathur, 1991).

Composting also leads to reduction in odour and the removal of pathogens. According to Sharma *et al*. (1997), wastes from wholesale fruit and vegetable markets, supermarkets and food processing are the best materials for composting. The principal bacteria which took the most active role in the bioconversion process were identified to be *P. aeruginosa* and *Bacillus* spp as seen in Table-1.

Table-1. Microbial community of digested Pig waste.

Pig waste before digestion	Digestate before application	Digestate after application
Pseudomonas aeruginosa	P. aeruginosa	P. aeruginosa
Bacillus cereus	Bacillus cereus	Bacillus cereus
Lactobacillus species	Lactobacillus species	-
Bacillus subtilis	Bacillus subtilis	-
Staphylococcus aureus	-	-
Escherichia coli	-	-
Salmonella typhimorium	-	-

Other bacteria which are pathogenic were destroyed by the process of composting as earlier mentioned above. The surviving bacteria which are known as bacteria bio-fertilizers could be used as microbial inoculants (Khosro and Yousef, 2012). They have been reported to accelerate certain microbial process to augment the extent of the availability of nutrients in a form which can be assimilated easily by plant.

The culture of microbial inoculums in compost has proven to accelerate the decomposition of organic residues and gives healthy harvest of crops (Abdul Halim, 2009). In our work, the elemental composition of the anaerobically digested slurry was determined to evaluate

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its nutrient contents. Nitrogen which is one of the major important nutrients very essential for crop growth was determined.

Generally, the atmosphere contains about 80 percent of nitrogen volume in free-state and the major part of the elemental nitrogen that finds its way into the soil is entirely due to its fixation by certain specialized group of microorganisms known as nitrogen-fixing-bacteria. Comparative evaluation of each of the digested category of slurry combinations showed variations in their nitrogen content (mg/100g) as follows: Pig waste only- Pw(1.70± 0.03), cassava waste only- Cw (0.61±0.02), food waste only-Fw (1.96±0.03),Pig waste and cassava waste- Pw+Cw (1.20±0.01), Pig waste and food waste- Pw+Fw (2.10± 0.02) as shown in Table 2 with the highest Nitrogen composition present in Pw+Fw.

The amount of other essential element for plant growth and high yield such as potassium, phosphorus, Magnesium were also determined. Pw+Fw showed highest K, P and Mg concentrations as 66.72± 2.36 mg/100g, 143.36± 2.36 mg/100g and 53.34±2.36 mg/100g respectively. There were no variations in the manganese concentration (0.03±0.00mg/100g) in all the four categories of waste combinations investigated (Table-2).

Table-2. Elemental composition of digested slurry of waste.

Nutrients	Anaerobic digested waste slurry			Anaerobic digested waste slurry	
(Mg/100g)	Pw	Cw	Fw	Pw+Cw	Pw+Fw
N	1.70±0.03	0.61±0.02	1.96±0.03	1.20 ±0.01	2.10± 0.02
K	40.00±5.32	31.2±2.89	36.73±2.33	26.70 ±2.89	66.72± 2.36
P	110.00±5.41	61.7±2.89	118.35±6.24	120±5.46	143.36± 2.36
Mg	26.70±2.89	21.7±2.89	26.76±1.29	31.7±2.89	53.34±2.36
Mn	0.02±0.00	0.01±00	0.03± 0.00	0.03±0.00	0.03±0.00

Pw= Pig waste; Cw = Cassava waste; Fw= Food waste. Each value represents mean (X±SEM) of triplicate values.

The increase in the amount of Phosphorus could be due to the presence of bacteria such as *Pseudomonas* and *Bacillus* in the biofertilizer which has been described as effective phosphate solubilizers (Igual *et al*., 2001). Symbiotic nitrogen fixer and phosphate solubilizing microorganisms play an important role in supplementing nitrogen and phosphorus to the plant, allowing a sustainable use of nitrogen and phosphate fertilizers (Tambekar *et al*., 2009; Khan *et al*., 2001).

In addition, according to Alam *et al* (2002), bacteria are more effective in phosphorus solubilization than fungi. In fact, among the whole microbial population in soil, phosphate solubilizing bacteria (PSB) constitute 1 to 50%, while phosphorus solubilizing fungi (PSF) are only 0.1 to 0.5% in P solubilization potential (Chen *et al.,* 2006).

Other soil microbial communities which could co-exist in the soil as P solubilizers are *Penicillium, Rhizobium, Aspergillus* fungi (Whitelaw *et al.*, 2000), although this was not reported in this work. The elemental composition is in the increasing order in each of the slurry waste as follows: Cw<Fw< Pw <Pw+Cw<Pw+Fw (Table-2).

Table-3. Proximate analysis of digested wastes.

Composition	**Anaerobic digested waste slurry**				
(%)	**Pw**	**Cw**	**Fw**	**Pw+Cw**	**Pw+Fw**
Moisture content	52.6 ± 0.05	49.1± 0.11	54.9 ± 0.13	52.14 ± 0.13	55.7±0.13
Protein	10.5 ± 0.06	3.8± 0.11	2.2 ± 0.10	7.5 ±0.06	13.2 ± 0.12
Ether extract	6.0 ± 0.06	1.7±0.11	6.7 ± 0.10	5.1 ± 0.08	7.3 ± 0.10
Ash	3.3 ± 0.04	2.4± 0.11	3.0 ± 0.13	4.2 ± 0.13	5.2 ± 0.13
Crude fibre	5.4 ± 0.06	6.6± 0.11	7.2 ± 0.12	5.9 ± 0.31	7.2 ± 0.12
Carbohydrates	22.2 ± 0.15	36.4± 0.21	8.8 ± 0.062	4.9 ± 0.08	11.4 ± 0.12

Pw= Pig waste; Cw = Cassava waste; Fw= Food waste. Each value represents mean (X±SEM) of triplicate values

Proximate composition of each of the digested slurry waste showed that Pw+Fw had the highest amounts as shown in Table-3. The pHs of the waste were monitored before and after application to the cowpea and maize.

There was a shift in the pH of Pw from 7.4 to 7.3; Cw from 3.5 to 6.9; Fw from 4.4 to 6.9; Pw+Cw from 6.5 to 5.2; Pw+Fw from 5.5 to 7.1. The shift in the pH could be due to metabolic activities and microbial interaction

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between the soil, other its component and added digested waste.

The best performance in mineral content and plant growth as seen in Pw+Fw could be due to the nearness to neutrality of its pH (Table-4).

Table-4. pH measurements of the digested slurry.

Digested slurry	pH (before application)	pH (after application)
Pw	7.4	7.3
Cw	3.5	6.9
Fw	4.4	6.9
Pw+Cw	6.5	5.2
Pw+Fw	5.5	7.1

Pw= Pig waste; Cw = Cassava waste; Fw= Food waste.

The average temperature of the field of planting over the period of experimentation was found to be between 33.57^{o}C to 40.8^{o}C (Table-5). Haven applied the composted slurry wastes to crop plantation at different concentrations, it was observed that each of the slurry wastes supported plant growth with increase and faster growth as compared to the control (without the bio-fertilizer added) although, with some variations as seen in the cowpea and maize plantation (Table-6).

Table-5. Field Temperature of planting over interval of days.

Day					Time		
	8am	10am	12pm	2pm	4pm	6pm	X±SEM*
1	27.0	29.0	38.0	39.5	37.9	30.0	33.57±2.24
5	28.0	33.0	39.5	40.5	42.0	35.0	36.33±2.17
10	30.0	38.0	41.0	45.0	47.0	33.5	39.08±2.68
14	29.5	39.0	44.0	46.5	49.0	37.0	40.8±2.92

*X±SEM (Mean±Standard Error of mean)

Table-6. Effects of bio-fertilizer on root elongation 14 days after application.

Digested slurry	1:6 (cm)	1:3 (cm)	1:2 (cm)			
	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
Pw	12.7	3.3	11.9	3.0	10.2	2.3
Cw	29.2	4.0	29.4	Ng	29.6	Ng
Fw	1.8	Ng	2.7	Ng	1.8	Ng
Pw+Cw	17	7.8	17.0	6.4	17.0	6.4
Pw+Fw	9.1	6.3	9.1	7.3	6.3	7.8
Soil Only	2.0	2.0	2.0	2.0	Ng	Ng

Pw= Pig waste; Cw = Cassava waste; Fw= Food waste; Ng = no growth

In addition, it was observed that the amount of the slurry used determined the rate of growth of the maize and cowpea seedling used. The proportion of bio-fertilizer applied to the soil was inversely proportional to the rate of growth of plant. Some earlier reporters have also described that the application of composts from different food wastes such as leaf compost (Maynard and Hill 2000) and compost from agro-industrial wastes (Garcia-Gomez et al. 2002) improve the physical properties of the soil and the yields of crops.

In summary, bio-fertilizers can be produced from wastes materials that pose to be environmental nuisance if well selected and harnessed with the hope of sustaining the soil properties and improve plant growth and productivity.

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