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Full Length Research Paper

Conversion of food wastes to organic fertilizer: A strategy for promoting food security and institutional waste management in Nigeria

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Abstract

Many institutions and communities in Nigeria produce high amounts of organic wastes such as food waste. Food wastes generated from canteens and restaurants in Nigeria present special challenges, as they produce odours, unaesthetic surroundings and attract vermin especially rodents, thereby causing health hazards through transmission of sanitation related infections. Therefore, a sound scientific approach in the management of food waste for improved environmental and public health status in Nigeria is highly required. The use of biological-mechanical treatment of the organic waste (composting process) is considered most appropriate as the process results in a final product that is sanitized and stabilized, high in humic substances and can be beneficially applied to land. Food waste has high energy content, and the primary factor in treating food waste is the physico-chemical characteristics of substrate, including particle size and composition. Composting converts organic waste stream generated into very rich organic fertilizer that is useful for crops growth. The focus of the study therefore, was to develop a composting process for managing food waste and assess its quality for possible use in plantain production.

Keywords: Food waste Organic fertilizer, Aerobic condition, Plantain production

INTRODUCTION

Food wastes could be regarded as pure streams of waste and they constitute a major burden to the environment such as odour emanation, vermin attraction, toxic gas emission and groundwater contamination. Food waste has high energy content and it seems ideal to achieve dual benefits of energy production and waste stabilization (Sun-Kee et al, 2004). The primary factor in treating food waste is the physico-chemical characteristics of substrate, including particle size and composition. According to Sun-Kee et al (2004), degradation of each component of food waste is affected by environmental conditions. Carbohydrate, cellulose, and protein have their own optimum pH and retention times for degradation (Sridhar and Arinola 1991). This means that the degradation of food waste could be enhanced by adjusting the environmental conditions depending on the state of degradation. Food wastes are commonly generated in homes, institutions (e.g. boarding schools/schools, prisons, sport camps, religious camps, industries e.t.c) and these wastes must be removed to provide a clean and healthy environment. These can be achieved through the use of composting to manage the waste and to produce compost that can be used in field crop production.

The slow release of Nitrogen supplied by food waste composts is ideally suited for urban landscapes where moderate, consistent rate of plant growth is highly desirable (Sullivan et al, 2001).

Plate 1: Food waste collected for composting

Plate 2: Organic fertilizer production machines

Application of any organic residue whether from plant or animal origins has direct and indirect effects on the physical, chemical and biological properties of the soil. These materials affect the soil physical properties (Hulugalle et al, 1996), soil faunal populations and the availability of soil nutrients (Wade and Sanchez 1983). One of the results of demographic and economic changes, in the tropical third world countries today is the shortening of the fallow period, which led to rapid decline in soil fertility and productivity. Agboola and Unama (1991) observed that one of the conditions to be satisfied in stabilizing agricultural systems in the humid tropics is to find means that will make soil organic matter adequately maintained at all times by preventing the amount already in the soil from being destroyed through cultural practices or by constantly adding organic materials to the soil.

Deliberate composting of organic materials aimed at providing favourable conditions to encourage microbial activity towards a speedy decomposition requires certain conditions, which favour the growth of the micro

organisms under aerobic condition. Donahue et al (1990) reported that the composting process was much faster and less odoriferous if done aerobically. The various factors which influence the rate of decomposition of organic materials during any composting process include: the C: N ratio, moisture content, particle size, temperature and pH control.

Composts made from organic wastes; when applied on land; increase soil organic matter and supply plant nutrients in a slowly available form (Hartz et al, 1996; Smith et al, 1992; Shanks and Gouin, 1989). For example, Smith et al (1992) reported significantly higher yield of field-grown cabbage and onion when the soil was fertilized with 25% compost. Similarly, Manios and Kapetanios (1992) reported a yield increase of more than 50% during the peak harvest of tomatoes when grown on soil covered with 1cm layer of municipal solid waste compost than without compost. In other studies higher yielding effects of compost application as fertilizer had been reported by Brechin and McDonald (1994) on onion and lettuce, Hountin et al (1995) on barley, Char-Fer-Lin (1981) on rice and Akanbi and Tairu (2000) on Celosia argentea and Joau et al (1997) on grass.

Plantains require large amounts of mineral nutrients to maintain high yields. These can be supplied either by growing the crop in very fertile soils or by supplementing moderate soil fertility with applied fertilizers. Plantains have a high demand for nitrogen and particularly potassium. The early stages of vegetative growth are critical for later bunch development. Very large quantities of nutrients are removed by a high yielding plantain and these must be effectively replaced to sustain the high production. Organic fertilization is an option for supply of nutrient elements to plantains. This necessitated the use of plantain as test crop in this study.

MATERIALS AND METHODS

The study was experimental and laboratory based in design. The composting process was aerobic windrow system, which produced finished compost in eight weeks. In the process, food residuals (see plate 1) generated from an institution with a population of four hundred and ninety six people, poultry litter and dried grass clippings were mixed in the ratio of 1:1:2 on dry weight basis to obtain optimal C: N ratio. To process the compost further to reduce the bulkiness and for sustainability, a pulverizer, shredder and mixing machines of 2 Tons/day design capacity were fabricated locally as shown in plate 2.

Plate 3: Field experimental strip

Plate 4: Field experimental strip 2

Composting chambers were constructed to make windrows of the fresh compost and allowed to attain maturity. The compost, soil and leachates were analyzed for Carbon, Nitrogen, Phosphorus, Potassium and selected parameters. Pre- planting soil analysis for the test and control soil was carried out. Descriptive and inferential statistics were used for data analysis. The organic fertilizer produced was used to grow plantain as test crop. The organic fertilizer produced was tested on an acid soil in the study area.

The experimental design used was the "strip trial" of Stewart (1947), FA0 (1970) and Adeoye (1986). This consist of simple sets of unreplicated plots designed to compare the yield and performance of a row of plantain sucker which is supplied with adequate amount of organic fertilizer with adjacent row in which organic fertilizer was not added (See plate 3 and 4). This was done in a plot measuring 4m by 12m. The plot was partitioned into two. One side for planting of the suckers of known heights, followed by application of the organic fertilizer, and the other side for planting of the suckers of known heights, but with no application of the organic fertilizer (control unit). The organic fertilizer was split applied. The organic fertilizer was applied immediately the sucker was planted and a second at six weeks after planting and subsequently at 12 weeks
interval, in a ring 10cm radius and 4cm deep. The compost application rate was 1kg / sucker at 1.6 tons / ha

RESULTS

The mean daily generation of food wastes was 1502 ± 0.15 kg and the food waste generated for a period of four years is as shown in figure 1. During the composting process the variation in temperature was 28^0C to 65^0C during dry season and 26^0C to 62^0C during rainy season due to variation in humidity. Chemical analysis showed that the matured compost consisted of the following: Carbon, 40.0 ± 5.5%; Total Kjeldahl Nitrogen, 3.56 ± 5.65%; Total phosphorus, 1.12 ± 5.53% and Potassium, 2. 03 ± 12.87%. The C: N ratio was 11.23, an indication of high nitrogen, resulting to fast decomposition of the biomass. The heavy metals (in mg/kg) included Lead (1.40 ± 1.32), Chromium (1.6 ± 7.12), Cadmium (1.1 ± 4.52), Zinc (0.55 ± 12.34), Nickel (1.41 ± 6.64) and

Fig 1: Summary of Food Waste Generated (Tons)

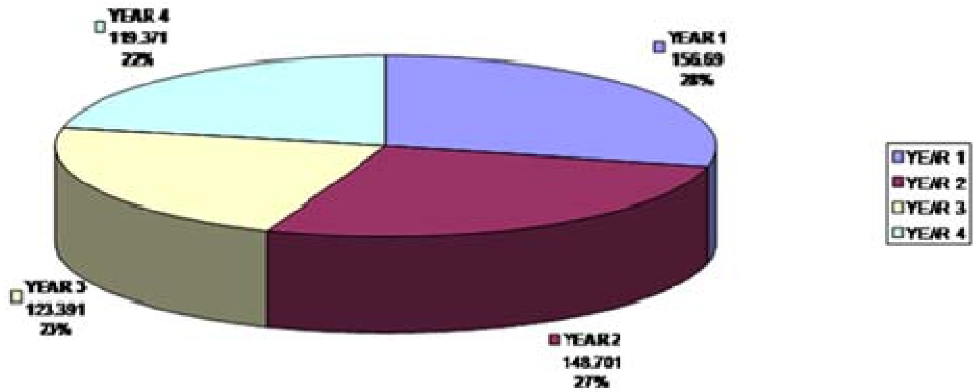

Table 1: Microbiological Examinations of Specific Indicators of the Organic Fertilizer (Milled and Packaged Compost)

INDICATORS	MPN COUNTS
Steptococci feacalis	1.0×10^{1}
E. Coli	1.0×10^{2}
Clostridium	2.0×10^{1}
Aspergilus niger	2.0×10^{2}
Coliforms	1.0×10^{4}
Staphylococcus sp	Nil

Copper (0.29 ± 14.11). The leachates contained: biochemical oxygen demand, 138.8 ± 3.45mg/l; chemical oxygen demand, 240.5 ± 5.64 mg/l; Turbidity, 3.22 ± 14.72 mg/l; Dissolved Oxygen, 5.6 ± 21.43 mg/l and Iron, 1.39 ± 3.67mg/l. The Compost had no *Clostridium sp;* but showed *Aspergilusniger* and *E.coli* of low count Detail of the result is as shown in table 1.

A comparative analysis of chemical and physical properties of experimental soil before planting and experimental soil after 10 weeks of application of compost at depth 0-15 cm showed that there was no significant difference in the parameters, except in Sodium, Magnesium, Sulphate, Lead, Chromium, Copper, Nickel and Iron where t = 0.52, 1.76, 0.36, 2.16, 0.08, 0.74, 0.07 and 1.29 respectively with $P < 0.05$. The value of the Zinc was significant where t = 7.32 with $P < 0.05$. The % Organic matter, % Total Organic Carbon (TOC), Available Phosphorus (mg/kg) and Potassium ((Cmol/Kg)) are significant where t = 20.19, 15.99, 17.46 and 11.79 respectively with $P < 0.05$. This indicates that the application of compost has a significant impact on the soil quality.

A comparative analysis of chemical and physical properties of experimental soil before planting and experimental soil after 10 weeks of application of compost at depth 15-30 cm showed that there was significant difference in pH (H_2O) 1:2; % Organic Matter, % Total Organic Carbon, % Sand; Al^{3+}, Ca^{+}, K^{+}, Cr^{6+}, and Cu^{2+}, where t = 35.54, 176.18, 185.03, 13.80, 31.44, 28.27, 63.37, 18.00 and 30.42 respectively with $P < 0.05$, while other parameters were not significant This indicates that the application of compost has a significant impact on the soil quality. All other heavy metals assessed with $P < 0.05$ were not significant.

The mean bunch weight of the experimental and control plantain were 7.80 ± 1.43 Kg and 6.5 ± 0.95 kg respectively (t=2.50, p< 0.05). The number of fingers in the experiment and control plantain were 17.8 ± 1.80 and 15.3 ± 2.05 respectively (t=3.19, p < 0.05). High yield of plantain, which is a staple food in most Nigeria communities, was recorded in the field where the organic fertilizer was used. Details of these results are shown in Tables 2, 3 and 4.

DISCUSSIONS

The sole aim of using organic fertilizer is to improve the soil fertility and to achieve high crops yield. Proximate and mineral analysis of the compost indicated the

Table 2: Growth monitoring of the suckers on soil treated with compost and soil without compost

Condition	Height between planted sucker and flowering stage (cm)	No. of days before flowering	No. of days between flowering and harvest	No. of days between planting of sucker and harvest of fruit
Soil Treated with Compost	203.4± 7.72	227.4 ±15.69	95.2±18.87	316.8± 14.16
Soil Not Treated with Compost	199.3 ±18.56	319.8 ±30.34	118±13.14	436.5± 35.33
t-test	0.71	9.37	11.80	10.89
p-Values	0.414	0.007	0.002	0.005

Table 3: Comparison of the plantain yields

Parameters	Experiment	Control	t-Test	p-Values
Bunch Weight	7.8 ± 1.43	6.5 ± 0.95	2.50	0.021
Hands No.	5.9 ± 1.16	5.3 ± 1.07	1.27	0.217
Fingers No.	17.8 ± 1.80	15.3 ± 2.05	3.19	0.004

Table 4: Comparative analysis of physico-chemical properties of experimental soil before planting and experimental soil after 10weeks of application of compost (Soil depth (0-15 cm))

	Soil depth (0-15 cm)	Before planting	10 weeks after application compost		
S/N	**Parameters**	**Mean + SD**	**Mean + SD**	**t-values**	**p-values**
1	pH, (H_2O) 1:2	5.37 + 0.252	6.7 + 0.40	23.74	0.001236
2	% Organic Matter	3.58 + 0.750	10.6 + 2.6	20.19	0.002020
3	% Total Organic carbon (TOC)	2.04 + 0.450	6.1 + 1.7	15.99	0.003956
4	Available Phosphorus, (mg/kg)	104.3 + 6.615	122.8 + 3.58	17.46	0.003087
5	Soil texture (gkg^{-1}):				
	Sand	65.6 + 1.484	5.66 + 1.65	49.34	0.000110
6	Clay	27.8 + 1.89	24.4 + 0.70	8.54	0.019235
7	Silt	6.6 + 0.436	19.0 + 1.07	345.53	0.000000
8	Exchangeable acidity, (Al^{3+}) (mg/kg)	3.81 + 0.326	1.61 + 0.12	120.40	0.000004
9	Calcium, (cmol/kg)	2.54 + 0.096	2.76 + 0.125	5.85	0.041871
10	Sodium, (cmol/kg)	2.3 + 0.372	2.47 + 0.165	0.52	0.489944
11	Potassium, (cmol/kg)	0.59 + 0.87	2.42 + 0.308	11.79	0.008898
12	Magnesium, (cmol/kg)	2.10 + 0.30	2.37 + 0.186	1.76	0.221813
13	Sulphate, (mg/kg)	24.94 + 5.05	27.33 + 4.72	0.36	0.565828
14	Lead, Pb^{2+} (mg/kg)	0.49 + 0.06	0.99 + 0.397	2.16	0.279665
15	Chromium, Cr^{6+} (mg/kg)	0.21 + 0.05	0.21 + 0.036	0.08	0.785859
16	Copper, Cu^{2+} (mg/kg)	0.78 + 0.06	0.99 + 0.155	0.74	0.481096
17	Nickel, Ni^{2+} (mg/kg)	0.42 + 0.15	0.45 + 0.118	0.07	0.792249
18	Total Iron, Fe^{2+} (mg/kg)	15.07 + 2.58	17.03 + 1.52	1.29	0.289749
19	Zinc, Zn^{2+} (mg/kg)	0.26+ 0.04	0.36 + 0.05	7.32	0.026865

Table 5: Comparative analysis of physico-chemical properties of experimental soil before planting and experimental soil after 10weeks of application of compost (Soil depth (15-30 cm))

S/N	Soil depth (15-30 cm)	Before planting	10 weeks after application of compost		
	Parameters	**Mean ± SD**	**Mean ± SD**	**t-values**	**p-values**
1	pH, (H_2O) 1:2	4.7 ± 0.23	6.3 ± 0.404	35.54	0.000338
2	% Organic Matter	2.79 ± 0.23	8.4 ± 0.695	176.18	0.000001
3	% Total Organic carbon (TOC)	1.59 ± 0.12	4.6 ± 0.364	185.03	0.000001
4	Available Phosphorus, (mg/kg)	97.4 ± 4.3	119.5 ± 2.581	8.87	0.096667
5	Soil texture (gkg^{-1}): Sand	66.3 ± 3.28	58.9 ± 1.069	13.80	0.005911
6	Clay	27.1 ± 1.55	26.6 ± 0.929	2.23	0.644597
7	Silt	6.5 ± 2.48	14.5 ± 0.346	5.53	0.142956
8	Exchangeable acidity, (Al^{3+}) (mg/kg)	3.00 ± 0.36	1.73 ± 0.156	31.44	0.000506
9	Calcium, (cmol/kg)	2.15 ± 0.16	2.66 ± 0.045	28.27	0.000714
10	Sodium, (cmol/kg)	2.35 ± 0.32	2.39 ± 0.159	0.04	0.851105
11	Potassium, (cmol/kg)	0.59 ± 0.34	2.41 ± 0.203	63.37	0.000045
12	Magnesium, (cmol/kg)	1.9 ± 0.6	2.31 ± 0.187	1.28	0.291249
13	Sulphate, (mg/kg)	24.68 ± 2.68	24.95 ± 4.564	0.01	0.931763
14	Lead, Pb^{2+} (mg/kg)	0.61 ± 0.06	0.88 ± 0.325	2.00	0.194741
15	Chromium, Cr^{6+} (mg/kg)	0.25 ± 0.02	0.19 ± 0.015	18.00	0.002827
16	Copper, Cu^{2+} (mg/kg)	0.65 ± 0.04	0.99 ± 0.099	30.42	0.000563
17	Nickel, Ni^{2+} (mg/kg)	0.47 ± 0.14	0.47 ± 0.069	0.01	0.914440
18	Total Iron, Fe^{2+} (mg/kg)	13.15 ± 2.55	15.00 ± 1.524	1.16	0.312198
19	Zinc, Zn^{2+} (mg/kg)	0.32± 0.04	0.33 ± 0.035	0.11	0.751822

fertilizing value of the compost produced, while the analysis of the soil revealed the level of its fertility. Pre-planting soil analysis for the test and control soil indicated an acid soil with organic matter of 3.58 %, total organic carbon (TOC) 2.04 %, available Phosphorus 104.30 mg/kg and Potassium 0.59 cmol/kg, including traces of heavy metals. An analysis of the test soil after ten weeks of addition of the compost, showed increase in pH with organic matter of 5.37%, total organic carbon (TOC) 3.07%, available Phosphorus 122.8 mg/kg and Potassium 2.42 cmol/kg.

There were increases in the level of some heavy metals such as Lead, Copper, Iron and Zinc, but were not significant. Compost, organic manure and farmyard manure have been reported to improve soil productivity in two ways: through the improvement of the physical conditions of the soil such as structure and tilth (Lombin et al, 1991) and/ through the nutrients it supplies and the way it supplies it (Adeoye and Agbola (1984); Agboola and Unamma (1991). Apart from compost rating as store-house for plant nutrients, as a major contribution to the cation exchange capacity and as a buffering agent against undesirable pH fluctuations (Jone and Wild, 1975; Adepetu and Corey, 1977; Katung et al; 1996), compost plays a key role in sustaining the soil fertility and physical conditions desirable for crop growth.

The presence of essential plant nutrients in the soil, which were enhanced by the addition of compost, implies that there will be readily available nutrients for the plantain uptake, thereby resulting in high yields. Other crops, especially staple foods in Nigeria, as in the case of plantain will also result to high yields when constant source of nutrients (compost) are applied into the soil. The use of this compost therefore, will improve the economy of subsistence and mechanized farmers. It will also go a long way in combating the national and global food security threats.

Production of compost from food wastes could be seen from the perspective of resource recovery from waste, while the application of compost is geared towards improving soil quality for improved crop production. The compost produced showed high fertilizing value. The developed technique produced three times Nitrogen content of the compost produced by other methods (1% to 2%). The compost was tested on plantain suckers because large quantities of nutrients are removed by a high yielding plantain and these must be effectively replaced to sustain the high production. Comparison of the crops yield from soil treated with compost and soil not treated with compost showed significant difference in bunch weight and finger numbers (P>0.05), but no significant difference in the hand numbers indicating that the treatment applied to the soil has significant effect on bunch weight and finger numbers of the plantains. This is in consonance with the work reported by Poulain (1976), Mahendra et al (1988), Akanbi and Tariu(2001), John (2003) and Taiwo and Oso, (2004), for the use of compost to grow crops such as maize, okra, citrus fruits, cassava, yams, tomatoes and others. Soil nutrients uptake could be influenced by ion absorption kinetics, root growth rate and activity, nutrient accumulation relatives to root characteristics, mass flow kinetics and crop demand or silk and consequently influence crop yields (Wade and Sanchez, 1983).

As a staple food in Nigeria, the growth of plantain with compost will boost plantain production that can be consumed or processed for starch production, which ultimately can be used as raw material in food and pharmaceutical industries. This technology is being promoted at community and institutional levels in Nigeria with the aim of promoting food security and reducing emissions known to be linked with climate change. Nigeria policies encourage indigenous technologies that prove beneficial in crops production, mitigating climate change effects and also serve as effective measure in managing institutional waste with resource recovery component.

CONCLUSION

Production of organic fertilizer from food wastes is an effective environmental sanitation and appropriate resource recovery strategy. The developed technique produced three times Nitrogen content of the compost produced by other methods (1% to 2%) and this is economically beneficial to farmers. The technology could be applicable in various food handling premises, restaurants, institutions, religious camps and sporting camps such as Olympic and commonwealth games camps. Organic fertilizer produced from food waste or organic wastes at commercial level is a measure of promoting waste to wealth program in Nigeria and other developing countries.

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