EFFECT OF POULTRY LITTER AND COW DUNG SUPPLEMENTATION ON THE BIOCONVERSION OF SOLID MUNICIPAL WASTE TO ORGANIC FERTILIZER

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ABSTRACT

The suitability of poultry litter, cow dung and leguminous plant supplementation in the bioconversion of solid municipal waste to organic fertilizer using indigenous microorganisms was investigated. The windrow method of composting was adopted and five mesocosms designated cell I, II, III, IV and V were used. One hundred and twenty kilogram of solid waste which included municipal solid waste, grasses and leaves were distributed into the various mesocosms. Cells I, II and III were supplemented with poultry litter, cow dung and leguminous plants respectively. A combination of all the three supplements was added to cell IV while Cell V received no supplement. Each of these were allowed to compost for 90days. Average temperature values ranging from 39-51^{o}C, 38-52^{o}C, 31-48^{o}C, 39-60^{o}C and 32-42^{o}C were recorded in cells I, II, III, IV and V respectively, throughout the composting duration. It was observed that total organic carbon, organic nitrogen and pH values decreased progressively with increase in composting duration. The pH values obtained decreased from 8.2 to 5.09 (cell I). 9.32 to 6.02 (cell II), 7.52 to 6.21 (cell III), 10.28 to 5.30 (cell IV) and 7.52 to 6.93 (cell V). At the end of composting, products of high nutrient value though to varying degree were obtained in various cells. The nutrient composition in cell I supplemented with poultry litter was 9.8mg/g (nitrate), 2.05mg/g (ammonium-nitrogen), 8.4mg/g (phosphate) and 0.04 mg/g (sulphate). Nutrient values of product obtained in cell II were 37.8mg/g (nitrate), 10.46 mg/g (ammonium-nitrogen), 15.82mg/g (phosphate) and 1.89mg/g (sulphate). In cell III, the values of nitrate, ammonium-nitrogen, phosphate and sulphate were 21.4, 5.73, 9.13 and 0.62 (mg/g) respectively. Highest values were obtained in cell IV with 85mg/g nitrate, 97mg/g ammonium-nitrogen, 28.4mg/g phosphate and 1.03mg/g sulphate. Loamy soil amended with the various produced compost, significantly influenced growth and development of bean seed used as indicator crop. Amendment of soil with NPK 15:15:15 yielded 15.3cm increase in leaf length and 8.25g crop dry weight. Analysis of variance indicated that there was a significant difference among the efficacies of various product as well as NPK fertilizer. However, t-test showed that there was no significant difference between the efficacies of product obtained from cell IV and NPK fertilizer. Simultaneously composting these wastes would act as potential sustainable environmentally friendly route of solid waste management and disposal as well as value added organic fertilizer for agronomic use.

INTRODUCTION

The increasing demand for food is one of the most important current issues faced by developing countries due to the rapid population increase (Nwabueze and Ugochinyere, 2006)). These population explosions have also brought about a phenomenal in the volume and diversity of solid waste generated daily giving rise to the pollution of air, water and soil. Municipalities, industries and agricultural farms are generating huge amounts of organic waste. These wastes in addition to disposal constraints are posing a serious threat to the environment and human health as well as toxicity to beneficial microfloral in soil (Ahmad *et al*., 2007). Notion of landfills for waste disposal has changed its dimension due to huge quantities of waste generation and reduced availability of dumping sites and environmental hazards (Chen and Sun, 2007). It is important to note that though these organic waste generated pose pollution problems, they are of considerably economic values in terms of nitrogen, phosphorus and potassium (Gajdos, 1998). Organic waste provide renewable raw materials for manufacturing products of high value through biological conversion and upgrading, thus, controlling the capacity

of soils to perform successfully and hence, sustaining agriculture (Hoitink *et al*., 1986).
Composting, recycling and waste management technology is defined as the process of aerobic and anaerobic degradation of organic waste principally of plant origin which may be agricultural waste, garden waste or domestic refuse (Nester *et al*., 2004).The sustainable development of environment and society is closely related to the natural recycling of materials through composting which increase soil organic matter content and fertility as well as reducing the use of chemical fertilizer and waste discharge.

Largely accessible organic wastes can be turned into valuable compost product for raising crops organically on one hand and getting them disposed off safely at the other end. Straight use of organic wastes has tribulations like transportation and handling, wider C:N ratio, high application rates, nutrient overloading, weed seeds, pathogens and metal toxicities. Composting bestows a tactic for coping high volumes of organic wastes in environmentally sound and desirable manners. Composted materials are remarkably regarded for their ability to improve soil health and plant growth, and suppress pathogens and plant diseases. The nature and composition of materials put into composting is imperative for its quality rationale. On the whole, principles and processes governing composting are not so straightforward. Also, little or no information (published data) exist especially, in the Niger Delta region of Nigeria regarding the response of crops to compost. Thus, this study was aimed at determining the quality of compost obtained from solid municipal wastes, the effect of readily available animal fecal matter on the compost quality as well as its resultant applicability on rainforest soils.

MATERIALS AND METHODS

Mesocosm Construction

Five mesocosms were used. They were made of wood and had a dimension of 1mx1mx1m. They were positioned at a distance of 3m apart and designated as cell I, II, III, IV and V

Source of Waste

The solid waste employed comprised of degradable municipal waste that were obtained in a refuse dump site located at Choba, Port-Harcourt, Rivers State. All non-degradable waste such as plastic, nylon and metals were carefully selected and separated. The supplements include cow dung, poultry litter and leaves of leguminous plant. The composition by weight of the individual waste used were degradable municipal waste (80kg), leguminous leaves (40kg), poultry litter (40kg) and cow dung (40kg)

Composting Operation

The various waste materials weighed as indicated above were placed into appropriate mesocosm as shown below:
Cell I: Degradable municipal waste + poultry litter
Cell II: Degradable municipal waste + cow dung
Cell III: Degradable municipal waste + leaves of leguminous plants
Cell IV: Degradable municipal waste + poultry litter + cow dung + leaves of Leguminous plants
Cell IV: Degradable municipal waste only (Control)

Composting was done for 90 days. At Day 0, all samples contained in the various mesocosms were watered. Subsequent watering was dependent on the results obtained from moisture content analysis. At the expiration of the 90 days (composting duration), each of the compost was allowed to stabilize for a period of one month (curing) after which, undegraded materials were selected and separated from the whole.

Temperature Measurement

Compost temperatures were taken at intervals of two days both in the morning and afternoon with a long thermometer probe measuring 65cm. Averages of weekly values were obtained and recorded.

Aeration

Compost contained in various mesocosms was turned to ensure aeration at intervals of 2 days for the 90 days period. Turning was however, done after temperature measurements.

Determination of Moisture Content

At regular intervals of 2 days moisture content was determined by the AOAC (1990) method. Compost was maintained at a moisture content that ranged between 50 and 60 (%). Moisture content below 45% was suggestive of watering and was done by sprinkling sterile deionized water. Average of weekly moisture content were obtained and recorded.

Determination of pH

On each analysis day (Day 0, 7, 14, 28, 60 and 90), pH of samples were determined using a pH meter (JENWAY, 3015 model) according to the AOAC (1990) method.

Enumeration/Identification of Microbial Isolates

The total heterotrophic bacterial and fungal counts were evaluated at Day 0, 7, 14, 28, 60 and 90. A sample of the compost was taken after turning adequately. One gram was weighed and diluted using the ten-fold serial dilution technique. Dilutions ranging from 10^{-2} to 10^{-9} were plated onto the surface of freshly prepared nutrient agar plates and those containing 30-300 colonies at the end of incubation duration were selected for bacterial enumeration. Sabauraud Dextrose Agar plates were used for the enumeration of fungi. Subsequent identification of pure bacterial and fungal isolates was done following criteria in Holt *et al*. (1994) as well as Barnett and Hunter (1972) respectively.

Determination of Nutrient Composition

The AOAC (1990) method was adopted in the determination of the nutrient composition of various composts. Nutrient evaluated include organic nitrogen, ammonium-nitrogen, phosphate, sulphate and total organic carbon

Evaluation of the Efficacy of Compost

Each of the compost produced was respectively mixed with loamy soil in a ratio of 1:5 and equal amounts were distributed into clean wide mouth containers as follows:

Loamy soil + product from Cell I
Loamy soil + product from Cell II
Loamy soil + product from Cell III
Loamy soil + product from Cell IV
Loamy soil + product from Cell V

Positive control consisted of the addition of 0.25g of NPK 15:15:15 to soil after one week of planting. This also served the purpose of comparative analysis of products and inorganic fertilizer. Negative control consisted of loamy soil only. Viable bean seeds which served as indicator seeds were then planted for a duration of 8 weeks. Leaf length and dry weight of harvested crop were the determinants of product performance. At intervals of 1, 3, 5 and 8 weeks, lengths of leaves were measured using a tiny string which was then compared to a meter rule to obtain the actual length.

At the end of the eight weeks planting duration, the whole crop was harvested and weighed as W_1 after which, it was heated at 105^{o}C in an oven to constant weight W_2. Dry weight (W_3) was obtained as W_1-W_2 = W_3

RESULTS AND DISCUSSION

Throughout the duration of the study (January to March), weekly temperature ranged from 28^{o}C to 60^{o}C as illustrated in Table 1. At week 1 temperature recorded were 30-40 ^{o}C, 34-38 ^{o}C, 28-31^{o}C, 30-39 ^{o}C and 28-32 ^{o}C for cells I, II,III,IV and V respectively. Probably, the periodic turnings that were done helped to control hike in temperature of various compost. It was observed that the temperature of various compost varied in direct proportion to the prevailing atmospheric temperature and as a result, average temperature recorded increased steadily with increase in the duration of the compost such that at week 5 (February), temperature recorded had increased to 40-55 ^{o}C, 36-41 ^{o}C, 32-42 ^{o}C, 44-58 ^{o}C and 32-40 ^{o}C in cells I, II, III, IV and V respectively. Also, remarkable differences in the temperature of various cells were noticed. This might be attributable to the levels of microbial activities taking place in the respective cells. Generally, the highest temperatures recorded were obtained in the mesocosm that contained degradable municipal waste + poultry litter + cow dung + leguminous leaves (cell IV) while the least temperatures were recorded in cell V that contained only degradable municipal waste. Trend in temperature variation of different compost was cell IV >

cell I > cell II ≥ cell III > cell V (Table 1).

Table 1: Average weekly compost temperature

Week	Average Temperature (^oC)				
	Cell I	Cell II	Cell III	Cell IV	Cell V
1	30-40	34-38	28-31	30-39	28-32
2	36-44	36-49	31-34	38-54	31-38
3	32-39	35-45	33-41	35-50	30-35
4	37-50	32-43	40-48	40-60	28-37
5	40-55	36-41	32-42	44-58	32-40
6	39-52	37-48	28-46	40-55	30-37
7	31-49	30-50	30-46	43-50	28-39
8	31-51	35-48	27-48	44-56	29-42
9	33-42	37-52	28-44	39-53	29-40
10	37-48	36-50	30-47	37-54	30-41
11	36-50	39-51	28-46	41-51	28-38
12	34-46	34-47	31-42	40-50	29-35

Simultaneously, the trend in the total heterotrophic bacteria count as well as total fungal load were highest in Cell IV > cell I ≥ cell II > cell III ≥ cell V (Table 2). At day 0, the total heterotrophic bacterial count obtained in cells I, II, III, IV and V were 6.41, 7.31, 6.93, 8.46 and 6.84 (log_{10}cfu/ml) respectively while the respective total fungal counts were 6.09, 6.14, 5.96, 6.38 and 5.92 (log_{10}cfu/ml).With the exceptions of cells III and V, a drop in the bacterial and fungal population were observed in the first seven days and thereafter, gradual increase in the population were observed until Day 60 for bacteria and day 90 for fungi. The initial drop in the bacterial and fungal counts may be attributed to the high pH (Table3) of the various compost while the progressive increase in microbial population observed afterwards, might be due to the introduced factors of frequent / periodic watering.

Table2: Total heterotrophic bacterial and fungal counts log_{10}(cfu/ml)

Day	Bacterial and fungal count log_{10}cfu/ml				
	Cell I	Cell II	Cell III	Cell IV	Cell V
0	$_b$6.41	$_b$7.31	$_b$6.93	$_b$8.46	$_b$6.84
	$_f$6.09	$_f$6.14	$_f$5.96	$_f$6.38	$_f$5.92
7	$_b$4.31	$_b$3.16	$_b$7.40	$_b$3.74	$_b$7.06
	$_f$3.69	$_f$3.58	$_f$4.04	$_f$3.38	$_f$5.95
14	$_b$8.03	$_b$9.03	$_b$8.42	$_b$3.61	$_b$7.19
	$_f$6.13	$_f$4.49	$_f$6.17	$_f$3.56	$_f$6.01
28	$_b$8.36	$_b$9.46	$_b$7.31	$_b$8.39	$_b$5.39
	$_f$9.46	$_f$4.98	$_f$6.25	$_f$7.97	$_f$4.15
60	$_b$7.33	$_b$7.78	$_b$5.04	$_b$10.8	$_b$4.31
	$_f$9.34	$_f$6.32	$_f$6.21	$_f$11.27	$_f$4.00
90	$_b$4.02	$_b$5.97	$_b$5.12	$_b$10.94	$_b$3.3
	$_f$9.39	$_f$8.45	$_f$7.01	$_f$10.00	$_f$6.00

Key: $_b$ = total bacterial count
$_f$ = total fungal count

Table 3: pH of various compost

Day	pH				
	Cell I	Cell II	Cell III	Cell IV	Cell V
0	7.59	8.02	7.12	8.28	7.02
7	7.46	7.70	7.03	8.21	7.08
14	6.88	7.06	6.91	8.03	7.12
28	5.89	7.14	6.63	6.91	7.05
60	5.73	6.71	6.54	6.05	7.01
90	5.09	6.02	6.51	5.30	6.93

At the onset, pH values ranged from 7.52 to 10.28. The pH values of mesocosms that received supplementation were higher than unsupplemented mesocosms. Poultry litter supplements resulted in a pH of 8.7. The pH value that accrued from cow dung (cell II) and leaves of leguminous plant (cell III) supplements were 9.32 and 7.83 respectively. The pH of cell IV (the mesocosm that received all three supplements) was 10.28. Control mesocosm had the least pH of 7.02. At Day 90, pH values recorded in cells I, II, III, IV and V were 5.0, 6.02, 6.21, 5.30 and 6.73 respectively (Table 3). These values obtained agree with the values reported previously by Katherine and Grant (2000). Generally, it was noticed that as composting duration increased, there were corresponding decreases in the pH values and this is probably due to the microbial breakdown of solid waste resulting in the concomitant production of organic acids as by products. Perhaps, this created a more favourable environment for microbial activity and multiplication and hence this may be accountable for the corresponding increases in both the bacterial and fungal loads observed in all mesocosms.

Importantly, the composting was carried out during the dry season when the humidity was quite low which in turn led to rapid reduction in the moisture content. Therefore, evaluation of the moisture content of the various compost were done at an interval of two days, thus the moisture content of various cells were controlled and ensured at a range between 45% and 60% as indicated in Table 6. Consequent upon close monitoring and control, there were no significant differences ($P > 0.05$) among

the moisture content of various mesocosms. Maintaining the moisture content at the aforementioned range was necessary since moisture facilitates microbial activity. Also, Cook *et. al*. (1994) reported that a moisture content between 50 and 60% was necessary for adequate and effective composting.

The changes in the pH and temperature of each of the compost might be responsible for the type of microbial successions noticed in this study. The predominant bacteria and fungi obtained are presented in Tables 5. The primary bacterial group isolated within weeks 1 and 2 of composting were *Pseudomonas, Bacillus,* and *Serratia.* The secondary bacterial group isolated between week 3 and 8 were majorly, *Pseudomonas, Bacillus, Flavobacterium, Micrococcus, Acinectobacter, Cellulomonas* while *Streptomyces*. *Bacillus, Enterobacter, Arthrobacter, Norcardia* and *Streptomyces* comprised the tertiary group isolated between week 9 and 12 of study period. Also, the primary fungal isolates were *Rhizopus, Mucor, Aspergillus* and *Fusarium* while the secondary and tertiary groups included *Penicillium, Geotrichum, Trichoderma* and *Botrytis* all of which are probably authocthonous members of the composting medium. Richards (1981) grouped the first colonizers in this work as primary saprophytes and states that there is no rule determining exactly what the succession might be. Also, previous workers (Miller, 1991 and Okani and Okazaki, 1995) had reported the occurrence of the isolated bacterial groups (especially the *Actinomycetes*) in soils and sediments. The emergence of *Arthrobacter* at Day 60 of composting is in agreement with the report of Miller (1991) that *Arthrobacter* predominates habitats in which metabolizable substrates have been degraded and in which humus has remained as the major fraction of organic materials.

The nutrient compositions of the various compost as determined are presented in Table 6. The values of nitrate, ammonium-nitrogen, organic nitrogen, total organic carbon, phosphate and sulphate obtained in cell I were 21.4, 5.73, 0.24, 7.4, 9.13 and 0.62 (mg/l) respectively. Similarly, composting activities in cell II yielded 37.8mg/l, 10.46mg/l, 4.97mg/l, 12.05mg/l 15.82mg/l and 1.89mg/l of nitrate, ammonium-nitrogen, organic nitrogen, total organic carbon, phosphate and sulphate respectively. The respective values obtained in cell III were 9.8, 2.05, 0.8, 5.6, 8.4 and 0.04 (mg/l). Highest values were recorded in cell IV with 85mg/l (nitrate), 9.17mg/l (ammonium -nitrogen), 0.8mg/l(organic nitrogen), 11.19mg/l(total organic carbon), 28.4mg/l(phosphate) and 0.04mg/l(sulphate). Cell V which did not receive any supplementation gave 0.5mg/l nitrate-nitrogen, 50.5mg/l (ammonium-nitrogen), 30.08 (organic-nitrogen), 38.1mg/l (total organic carbon), 7.72mg/l (phosphate) and 1.33mg/l (sulphate). The very high values of organic-nitrogen, ammonium-nitrogen and total organic carbon obtained in this mesocosms indicates that microbial activities were quite limited and this is most likely, as a result of the absence of supplementation

Product efficacy test results as well as a comparative analysis of various products and inorganic fertilizer (NPK 15: 15: 15) are depicted in Table 7. The various products supported the growth and development of the indicator crop (beans) to varying degree. Increase in leaf length obtained after a two month planting period using products obtained from cell I, II, III, IV and V as shown in Table 7, were 7.3, 10.5, 3.5, 15.0 and 3.8 (cm) respectively . NPK 15:15:15 gave 15.3cm increase while loamy soil alone yielded 1.18cm increase. Dry weight of crop planted in soil amended with compost obtained from cell I, II, III, IV and V were 2.13, 3.4, 1.03, 7.9 and 0.78 (g) respectively as shown in Table 7. Amendment of soil with NPK 15:15:15 yielded 8.25g crop dry weight while the dry weight of crop harvested from loamy soil without amendment (negative control) was 0.53g. Analysis of variance indicated that there was a significant difference among the efficacies of various product as well as NPK fertilizer. However, t-test showed that there was no significant difference between the efficacies of product obtained from cell IV and NPK fertilizer. Trend in the performance of products was NPK fertilizer ≥ Product from cell IV > Product from cell II ≥ Product from cell I > Product from cell III ≥ Product from cell V.

CONCLUSION

Results obtained showed that composting under controlled conditions of watering, turning and temperature encouraged microbial activities resulting in acceptable compost. The findings in this present study indicate that the addition of nitrogen-rich animal fecal matter to solid waste would enhance biodegradability. Cow dung and poultry litter, have evidently been shown to increase microbial load which in turn increased biodegradative rate and hence achieving high quality organic manure and consequently, crop yield. Secondly, the study demonstrates clearly that the production of organic fertilizer from solid municipal waste is highly feasible. Thus, it can be a crucial framework for waste management as it is socially sound, ecologically sustainable and economical.

Considering the attitude of waste management in our country especially in the Niger Delta region imbibing this technology becomes imperative. Whereas on one hand, it shall help to drift to the production of safer organic foods, on the other hand, it comes with the spirit of eco-friendliness and good environmental aesthetics. Therefore, organic municipal wastes which were hitherto, regarded as worthless, can now be re-valued as highly energetic raw materials for organic fertilizer production processes consequently, averting the resultant health issues implicated with the consumption of crops produced by inorganic fertilization.

Table 4: Average weekly moisture content of various compost

Week	Average Moisture Content (%)				
	Cell I	Cell II	Cell III	Cell IV	Cell V
1	51	55	60	52	51
2	49	50	52	46	44
3	55	60	57	55	58
4	50	56	54	49	54
5	46	53	50	50	60
6	52	50	56	51	55
7	57	48	47	56	53
8	58	45	51	47	50
9	55	47	50	49	50
10	50	50	49	52	51
11	48	49	53	47	52
12	47	51	50	50	48

Table 5: Predominant bacterial and fungal Isolates

Period (week)	Group	Isolate
1-2	Primary Saprophyte	*Pseudomonas, Bacillus, Serratia*, *Rhizopus, Mucor, Aspergillus* and *Fusarium*
3-8	Secondary Saprophyte	*Pseudomonas,Bacillus, Flavobacterium, Micrococcus, Acinectobacter, Cellulomonas Streptomyces*, *Penicillium, Geotrichum, Trichoderma* and *Botrytis*
9-12	Tertiary Saprophyte	*Bacillus, Enterobacter, Arthrobacter, Norcardia*, *Streptomyces Penicillium, Geotrichum, Trichoderma* and *Botrytis*

Table 6: Nutrient composition of various compost

Nutrient	Concentration (mgl^{-1})				
	Cell I	Cell II	Cell III	Cell IV	Cell V
Nitrate nitrogen	21.4	37.8	9.8	85	0.5
Ammonium nitrogen	5.73	10.46	2.05	9.7	30.5
Organic Nitrogen	0.24	4.97	0.8	13.9	50.08
Total organic carbon	7.4	12.05	5.6	11.10	38.1
Phosphate	9.13	15.82	8.4	28.4	7.72
Sulphate	0.62	1.89	0.04	11.03	1.33

Table 7: Sample efficacy test (Length of leaf (cm) and dry weight (g) of indicator crop)

Week	Leaf Length (cm)						
	Cell I	Cell II	Cell III	Cell IV	Cell V	NPK	Loamy soil only
1	4.4	5.3	2.7	3.3	3.1	2.1	1.0
3	5.2	7.4	3.0	6.2	3.3	5.7	1.1
5	6.9	8.1	3.4	9.8	3.6	10.5	1.15
8	7.3	10.5	3.5	15.0	3.8	15.3	1.18
Dry weight (g)	2.13	3.4	1.03	7.9	0.78	8.25	0.53

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