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Research Article

Determination of Bacteriological Quality of Animal and Municipal Solid Waste using Windrow and Open Pile Composting Techniques in Zaria, Nigeria

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Abstract: The aim of this study is to determine the effectiveness of simple composting techniques at improving the overall quality of finished compost. Composting of raw organic waste can be used of agricultural or domestic use and compost may possibly increase the risk of disease transmission by a number of mechanisms. The Open pile and the Windrow methods where used in composting poultry, cow and Municipal solid waste for 12 weeks and the Total Plate and Total Coliform counts were determined. The results showed a steady decline in the first seven weeks of composting and the overall quality of the final compost meet the recommended standard by the United State Environment Protection Agency for finished compost. Large scale, wide spread and further researches are highly recommended.

Keywords: Animal waste, bacteria, composting, municipal solid waste, windrow and open pile

INTRODUCTION

Animal manure has been found to be the source of more than 100 pathogens, including bacteria, parasites and viruses that could be transmitted from animals to humans (Jones, 1982). Many of these pathogens survive well in the environment and frequently persist in livestock operations. Infections with livestock and poultry with such pathogens may not produce any clinical disease. Animals act as asymptomatic carriers in amplifying the pathogenic agent that goes back into the environment in a cyclic manner. In most cases the producer would be unaware that the manure or bedding from animal quarters contains these pathogens (LIoyd and Jiewen, 2004).

Salmonella has more than 2300 serovars of which many infect humans and warm blooded animals. During the anaerobic incubation *Salmonella* sp., were detected until 32 day of incubation, while during the aerobic incubation *Salmonella* sp., decreased to an undetectable level in about 15 days. Burge *et al*. (1978) reported that *Salmonella* were destroyed in 10 days by aerated, static pile composting of raw sludge in 15 days in turned windrows. The *Salmonella* were eliminated after 14 days at 55 to 60°C. At a higher temperature of 60 to 70°C, *S. newport* could not be isolated from composted sewage after 3 days and at a similar temperature (60 to 65°C) *S. typhimurium* and *Serratia marcescens* inoculated into a composting drum containing septic waste, biosolids and municipal solid wastes could also not be isolated after 3 days (Krogstad and Gudding, 1975).

Himathongkham *et al*. (1999) reported that this organism declined exponentially in cattle manure with a Decimal Reduction Time (DRT) from 6 days to 3 weeks and in cattle slurry with a DRT of 2 days to 5 weeks. The most rapid destruction was achieved at 37°C and numbers of *E. coli* declined at approximately the same rate as *S. typhimurium*. In poultry manure the concentration of *E. coli* O157:H7 and *S. typhimurium* also declined exponentially. The DRT ranged from 12 h to 1-2 weeks at 4°C (Himathongkham *et al*., 2000).

Survival for shorter periods in composted wastes should be predicted, although Droffner and Brinton (1995) reported the survival of Salmonella and *E. coli* in industrial composts for up to 59 days at 60°C. This study relied upon the use of gene probes rather than isolation of viable organisms, which may account for the extended survival period reported. In contrast, Turner (2002) found that an indicator strain of *E. coli* was inactivated in farmyard manure, pig faeces and straw if kept at 55°C for more than two hours. It was, however, still viable after 72 h at 50°C. Coliforms grew in the compost if the process was carried out at mesophilic (37°C) temperatures. Knoll (1961) described several experiments where Salmonella strains were subjected to different composting temperatures. After 14 days at 55 to 60°C the final compost did not contain salmonellas. Thermal destruction of bacteria may depend on factors other than temperature, including moisture content, ammonia concentration and the presence of other organisms. In industrial compost Salmonella and *E. coli* were found to survive for 59 days at 60°C (Droffner and Brinton, 1995). Lung *et al*. (2001) inoculated *E. coli* O157:H7 and *Salmonella*

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enteritidis into a bench-scale cow manure composting system at a level of 10^7 organisms per gram of raw compost. *E. coli* was not detected after 48 h at 45°C and *S. enteritidis* after 72 h. When the compost was held at 25°C the concentration of seeded organisms did not decline. The effect of temperature was also demonstrated by Gibbs *et al*. (1998). They investigated the effect of two windrow composting systems on the survival of Salmonella. Salmonella was not detected after composting at 52 to 53°C but was isolated from 7 of 11 samples at 30 to 40°C. Tiquia *et al*. (1998) found that Salmonella was no longer detected after composting for 3 weeks in a mixture of partially decomposted pig manure and sawdust at temperatures between 64 and 67°C. Hirn *et al*. (1983), using compost derived from sewage sludge and food waste, did not isolate Salmonella. Faecal streptococci and *C. perfringens* were always present, although numbers declined by 2 to 3 logs during a 6- to 7-week period. Plym-Forshell (1983) studied the survival of salmonellas in cattle and pig manure mixed with straw. *S. dublin*, *S. senftenberg* and *S. typhimurium* survived for less than 7 days in cattle manure at 55 to 60°C or pig manure at 54 to 60°C. In contrast, *S. derby* persisted for more than 140 days at 2 to 19°C. Russ and Yanko (1981) studied the kinetics of development of sludge compost inoculated with Salmonella sp under aerobic and anaerobic conditions. During the anaerobic incubation Salmonella sp were detected until the 32nd day of incubation, while during the aerobic incubation Salmonella sp decreased to an undetectable level in about 15 days. Burge *et al*. (1978) reported that Salmonella were destroyed in 10 days by aerated static pile composting of raw sludge and in 15 days in turned windrows.

Manures are generally packed in bags and sold to farmers for land application. Some big farms also manufacture compost by primitive methods and sell the product in unlabeled bags and are used widely by farmers as plant fertilizer. Many African countries have not established laws governing the production and sale of organic fertilizers, which should propose some specifications and regulations for compost quality (GCST, 2006). In Nigeria, there are neither mechanisms nor organizations responsible for the evaluation of compost, which may result in low quality that is harmful to public heath, plant and the environment. There is paucity in information concerning the quality assessment of the compost produced in Nigeria. Accordingly, little information is available about maturity and stability indices of local composts.

The aim of this study is to Asses the microbial qualities of poultry, cow and municipal solid waste after 12 weeks of composting.

MATERIALS AND METHODS

The types of waste collected and the quantities collected are Municipal solid waste, Cattle waste, Poultry waste.

The waste samples were collected for composting using a shovel and a clean container that can carry up to 50 kg of each waste to the composting site (was sufficient for proper composting).

Each waste type was composted for 12 weeks each over a period of 6 months between September 2011 to February, 2012 (Samples were collected on a weekly for the 12 weeks) A total of 432 samples were collected within the said periods.

The static aerated piles and windrow methods were used to compost various waste types.

Sample collection: The composting samples were collected in sterile stainless spoon to a depth of 3 cm into a sterile conical flask. These were transported in a cold pack to the laboratory for analysis that where carried out within 6 h of collection.

Determination of total bacterial count: Samples where diluted (10^{-1} to 10^{-6}) using serial dilution method. The last two dilutions (10^{-5}, 10^{-6} where inoculated in duplicates on the Plate Count Agar (PCA) using the pour plating method. Total bacterial count where determined after incubation at 37°C for 24 h (Sikora *et al*., 1983).

Total coliform count: Were determined using EMB (Eosin methylene blue agar). About 25 g of composting waste sample collected where weighed into 225 mL of sterile distilled water and further diluted serially (10^{-1} to 10^{-6}). The last two dilutions were plated out in duplicates using the pour plating method. The plate were incubated at 37°C for 24 h after which the total coliform count were determined (Sikora *et al*., 1983; Yahaya *et al*., 2011).

RESULTS

A total of 432 samples, 72 from each sets of compost were collected for microbiological monitoring.

Table 1: Mean of the total plate and coliform counts of the compost (log_{10} cfu/g)

	Total plate count			Total coliform count	
Week	N	Mean	S.D.	Mean	S.D.
Week 1	72	9.43^{a}	0.058	9.41^{a}	0.055
Week 2	72	8.44^{ab}	0.592	8.26^{bc}	0.563
Week 3	72	7.57^{ab}	0.610	7.25^{c}	0.740
Week 4	72	6.83^{ab}	0.825	6.08^{d}	0.759
Week 5	72	6.54^{c}	0.803	5.44^{e}	1.330
Week 6	72	5.89^{d}	0.581	5.14^{f}	0.829
Week 7	72	5.55^{e}	0.481	4.31^{f}	1.267
Week 8	72	5.20^{f}	0.550	3.81^{g}	0.854
Week 9	72	5.08^{g}	0.558	3.14^{h}	0.856
Week 10	72	4.86^{h}	0.179	2.86^{i}	0.894
Week 11	72	5.11^{i}	0.179	2.47^{j}	1.234
Week 12	72	5.08^{j}	0.324	2.44^{k}	1.219
Total	864	6.30	1.530	5.05	2.416

S.D.: Standard deviation; Means with different superscript are significantly different ($p<0.005$) using Duncan's multiple range test

Table 2: Mean and standard deviation of compost for each week counts (log_{10} cfu/g)

		N	Mean	S.D.
Total plate count	Composit 1	72	6.01[a]	1.454
	Composit 2	72	5.91[ab]	1.429
	Composit 3	72	6.40[ab]	1.462
	Composit 4	72	6.81[ab]	1.539
	Composit 5	72	6.51[c]	1.661
	Composit 6	72	6.16[d]	1.489
	Total	432	6.30	1.530
Total coliform count	Composit 1	72	4.57[a]	2.583
	Composit 2	72	4.60[b]	2.441
	Composit 3	72	5.24[b]	2.694
	Composit 4	72	5.27[b]	2.190
	Composit 5	72	5.62[b]	2.399
	Composit 6	72	5.00[c]	2.034
	Total	432	5.05	2.416

S.D.: Standard deviation; Mean with different superscript are significantly different ($p<0.005$) using ANOVA and Duncan's multiple range test (in between groups within the groups) but show no significant differences between the TPC and TCC $p>0.005$ (0.387)

Table 3: The weekly mean total plate counts for the various waste composted using the two composting techniques (log_{10} cfu/g)

	Mean value		
Week	Cow	Poultry	Municipal solid waste
Week 1	9.412	9.437	9.428
Week 2	8.628	8.245	8.449
Week 3	7.732	7.397	7.592
Week 4	6.804	6.603	7.091
Week 5	6.464	6.324	6.829
Week 6	5.833	5.653	6.172
Week 7	5.536	5.507	5.607
Week 8	5.047	5.189	5.367
Week 9	4.951	5.049	5.237
Week 10	4.843	4.767	4.973
Week 11	5.079	5.048	5.198
Week 12	5.000	5.075	5.174

The rate of decline showed a significant weekly difference among the various waste types ($p<0.005$, 0.001) but showed no significant difference between the different waste types $p>0.05$ (0.418, 0.174) respectively

Table 4: The total plate count for the two composting techniques used for 12 weeks (log_{10} cfu/g)

	Windrow		Open pile	
Location	Mean	S.D.	Mean	S.D.
Week 1	9.426[a]	0.059	9.426[a]	0.059
Week 2	8.450[b]	0.612	8.431[b]	0.590
Week 3	7.539[c]	0.613	7.608[c]	0.622
Week 4	6.703[d]	1.007	6.962[d]	0.593
Week 5	6.521[e]	0.832	6.557[e]	0.797
Week 6	5.763[f]	0.663	6.009[f]	0.473
Week 7	5.461[g]	0.501	5.639[g]	0.456
Week 8	5.202[h]	0.580	5.201[h]	0.536
Week 9	5.046[i]	0.594	5.112[i]	0.535
Week 10	4.816[i]	0.212	4.907[i]	0.202
Week 11	5.071[i]	0.185	5.146[i]	0.169
Week 12	5.128[i]	0.425	5.038[i]	0.177

S.D.: Standard deviation; Means with different superscript are significantly different ($p<0.05$) using Duncan's multiple range test; The total plate count showed no significant difference between the windrow and the open pile compost $p>0.5$ (0.151)

Comparing the mean of counts from the different compost studied the results showed that the mean values for the final compost met the recommended 2.0×10^7 cfu/g (Table 1 and 2). In comparing the total pate counts and the total coliform counts, there is a significant reduction in counts between the weeks ($p<0.005$).

The effect of composting on the different waste types (poultry, cow and municipal solid waste) weekly, showed a general decline in the total viable and total coliform count with the highest decline in municipal solid waste and lowest in poultry waste. The rate of decline showed a significant difference among the various waste types ($p<0.005$, 0.001) (Table 3). The results for the two types of composting techniques used also revealed a steady decline in the mean count for both. The indigenous population of total heterotroph mesophilic bacteria in the fresh material was high for the waste composted possibly because the stock piling of the waste may have allowed decomposition to begin before day 0. The total plate count showed no significant difference between the windrow and the open pile compost $p>0.5$ (0.151) (Table 4). The plate and the coliform count showed no significant difference between the different waste types $p>0.05$ (0.418, 0.174) respectively.

DISCUSSION

It is a well known fact that biologically processed organic manures are better than inorganic artificial fertilizers. One of the front liners in the world today is environmental protection and waste management. In addition, the government of Nigeria is encouraging agriculture and local production as against importation. One of the ways to merge these is the conversion of organic wastes to manure for agricultural use. During composting, the microorganisms use the organic matter as a food source, the process produces heat, carbon dioxide, water vapour and humus as a result of growth and activities of microorganisms (Tiquia, 2005). Monitoring of the microbial succession is important in the effective management of the composting process as microorganisms play key roles in the process and the appearance of some microorganisms reflects the quality of maturing compost (Ryckeboer *et al*., 2003).

In this findings, the method of composting did not affect microbial counts ($p>0.05$). Microbial count were significantly $p<0.05$) affected by duration of composting (Table 1). In the open pile and the windrow techniques used in composting the waste, there was an initial increase in microbial count followed by steady decline. The initial increase could be due to the utilization of nutrients by the microorganisms present (Tiquia, 2005). The decrease in count may be due to the depletion of nutrients in the waste, accumulation of toxic products and unfavorable growth environment (Kowalchuk *et al*., 1999). There are currently no reported values for an acceptable viable microbial count in finished compost. However, Atkinson *et al.* (1996),

stressed that the microbial count should be low and should not contain significant quantities of viable pathogenic organisms.

The microbial count of the different compost groups is illustrated in Table 1 and 2. The indigenous population of total heterotrophic mesophilic bacteria in the fresh material was high for this type of material, possibly due to the gradual collection and stockpiling of the various wastes, which may have allowed some decomposition to begin before day 0. The compost was sampled on a weekly.

The effect of high temperatures exercise on the microbial population is enormous, as high temperatures favor cellulose degradation, bacteria demonstrated a high count at the first few weeks of the study their numbers declining steadily (Table 1). This decline could be attributed to the fact that cellulose may become inaccessible to enzymatic attack associated with protective substances such as lignin. During composting, pathogens reduction is accomplished to some degree of several processes, including completion between indigenous microorganisms and pathogens, antagonistic relationship between organisms, the action of antibiotics produced by certain fungi and actinomycetes, natural die-off in compost environment, production of toxic by products such as gaseous ammonia, nutrient depletion and thermal destruction (Hogg *et al*., 2002; Wichuk and McCartney, 2007).

The pilot laboratory scale data may be insufficient to accurately predict indicators and pathogen survival times in full-scale composting facilities. During full scale windrow and open pile composting, reduction of all organisms took significantly longer than the pilot scale experiment and *E. coli* reduction took more than 5 weeks.

According to USEPA (1999) standard, the minimum temperature of 55^{o}C should be maintained for 3 days consecutively, unless the windrow composting is employed. For windrow, a minimum temperature of 55^{o}C for 15 days consecutively should be maintained with a minimum of 5 turning during the high temperature period.

CONCLUSION

A wide range of waste can be composted using the above composting techniques but regulations should place restrictions on the materials that can be used in organic farming and production systems. The basis for these regulations should be based on current scientific understanding. There is little research specifically on composting in organic farming and production systems.

There should be greater effort to be put into technical transfer of current knowledge on composting to inform organic farmers and growers and regulators about issues of concern.

Composting is not seen as a key process in the waste hierarchy in the Nigeria system and markets for compost are not available even though they tend to have an important role in reducing the volume of biodegradable municipal waste going to the open field.

To make an appreciable difference there is need for large-scale and widespread use of compost. Further research is needed to quantify the short-term benefits of compost use in soil.

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