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*Full Length Research Paper*

# Influence of composting techniques on microbial succession, temperature and pH in a composting municipal solid waste

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**Composting of urban wastes was carried out using both passive aeration technique (PACT) and conventional pit method. Feacal c*oliforms, Pseudomonas, Streptococcus, Proteus ,Seratia* and *Bacillus* species as well as fungi were isolated at mesophilic stage of degradation. A number of these microorganisms did not grow at the thermophilic stage but grew at cooling down stage. The trends in microbial succession in the composting wastes in pot and pit were somewhat similar. There was, however, repeated re-heat after turning the wastes in the pit until about 5 months later. Each time the waste was turned in the pit, there was an increase in temperature until the 21st week. Temperature however, stabilized at the 7th week in the pot. pH also stabilized as the composting process progressed in the pit. Good quality compost was obtained in 5 weeks when PACT was used. Conventional pit method lasted over several weeks.**

**Key words**: Municipal wastes, passive aeration, pit composting, temperature, microbial succession.

## INTRODUCTION

Composting is an age long process. Before the introduction of inorganic fertilizers to Nigeria, resource-poor farmers used composts to fertilize their soils. However, the technique of preparation is laborious and the process is practically slow. It takes between 5 and 6 months to complete. During the composting period, labile carbon (C) compounds are lost, while more complex substances, such as humic acids, are synthesized (Riffaldi et al., 1992). Once the microbial degradation has been stimulated to a certain level, the faunal effect will become quantitatively important (Tian et al., 1995). Adequate knowledge of microbial succession is therefore, very important in any chosen composting method. Various biological studies have been carried out to identify the major microbiological agents responsible for biodegradation. For example, Macdonald et al. (1981) noted that the composting process was brought about by several organisms such as bacteria, fungi, actinomycetes and protozoa and may also involve invertebrates such as nematodes, potworms, earthworms, mites and various other organisms. Singh (1987), however, noted that the sole agents of decomposition of carbonaceous materials are the heterotrophic microorganisms.

Hudson (1986) described succession in the aerobic process, noting that the composition of active mycoflora of composting wastes normally shifts from predominantly mesophile in the early stages of thermogenesis to one of predominantly thermophiles at the peak of the heating cycle. He identified the mesophilous *Clasdosporium herbarium*, *Aureobasidium*, *Alternaria alternata* and *Epicoccum purpurascens* at the beginning of composting. Wani and Shinde (1976) looked into inoculation with cellulolytic organisms and reported enhanced decomposition of treated wastes over the untreated.

Generally, successful composting depends on a number of factors that have both direct and indirect influence on the activities of the microorganisms. They include the type of raw material being composted, its nutrient composition, moisture content, temperature, acidity or alkalinity and aeration. The microorganisms that do much of the work need high temperatures, plenty of oxygen, and moisture. In the traditional method of composting, the influence of the

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listed factors had been largely ignored. The final composts obtained from such unimproved method are poor in quality. It has therefore become highly imperative to develop an alternative technique for the needed good quality compost in a shorter period and identify the specific microorganisms involved in the degradation with the aim of improving the biodegradation process. Any composting method that does not allow for adequate aeration and building-up of relatively high temperatures will not allow the relevant microflora to colonize and degrade the wastes. The present investigation, therefore, was carried out to assess the impact of passive aeration method of composting on microbial succession in composting urban wastes.

## MATERIALS AND METHODS

### Passive aeration composting technique

Plastic barrel (250 L size) with 3 holes made at intervals on the side about 30 cm from the bottom was used for composting. Aeration was provided passively through open-ended air intake bamboo pipes (5.0 cm in diameter) inserted into the holes through which fresh air flowed by itself, as the heat generated by biological oxidation caused warm air to escape through another vertically inserted (half way in the barrel) open-ended bamboo pipe on which were holes. The waste mixture (municipal wastes and poultry manure, combined in ratio 3:1 on their dry weight basis) was properly mixed on a concrete platform with occasional watering to bring the final moisture to 58% (w/v) before it was packed into the barrel.

### Pit composting method

A pit 3 x 2 x 0.5 m, was piled with chopped municipal solid wastes and poultry manure in the ratio 3:1, also on their dry weight basis and moistened with water to bring the final moisture level to 58%. Ten layers of the pile were made and the pit was covered with corrugated iron sheet to shield it from rain drops. In order to allow for turning (aeration) a similar pit was dug by the side. The composting wastes were turned once in every 5 weeks.

### Temperature determination

The ambient temperature was continuously monitored on a Salmoiraghi Co. thermometer model 17506. Process temperature was determined weekly by inserting the thermometer 25 cm deep into the pile or the composting wastes in the pot.

### pH determination

pH determination was performed weekly from sub-samples collected from six parts of composting wastes with long forceps. The samples were pooled from the various parts and suspended in water (w/v, 1:10), shaken for 30 min on rotary shaker and the pH of the supernatant was determined using a pH meter (Scientific Instruments Co. (Italy) model 9000/3).

### Nutrient composition determination

Similar sampling technique to that of pH parameter was adopted. The various samples, (six in number) were pooled, dried at 70$^{o}$C to constant weight and ground. Organic carbon content was determined using the method described by Walkey and Black (1934). Percent nitrogen (N) determination was by micro-kjedahl method according to Bremer (1960), while phosphorus (P) was by wet oxidation (A.O.A.C. 1980). Potassium was determined by dry ashing (A.O.A.C., 1980).

### Microbiological studies

One gram of experimental material each was obtained from pooled samples obtained 5 h after setting up the 2 composting processes for the isolation and identification of the mesophilic microorganisms while about a week later, compost samples were obtained from the composting wastes in the pot for isolation and identification of the thermophiles. However, isolation and identification of microorganisms in the pit at the thermophilic stage were carried out at every heating cycles after turning the composting wastes from one pit to the other untill there was no reheat. At cooling down stage (4 weeks after compost initiation for PACT technique and 20$^{th}$ week for Pit) microorganisms were isolated and identified. At every stage, one gram of experimental material obtained from either the pot or pit was suspended in 99ml of sterile distilled water and stirred with Gallenkamp flask shaker for 60 min.

### Isolation and identification of actinomycetes

Isolation and identification of microorganisms in wastes in the pot and pit were done at mesophilic, thermophilic and the cooling down stages. The two media used; glycerol agar and yeast-malt-extract plus glucose agar were formulated by Tendler and Burkholder (1961) and to suppress bacterial and fungal growth, 1ml per plate of the following solution was added: 30 mg nystatin, 0.6 mg streptomycin, 1 mg polymycin, 30 mg oxytetracycline, and 20 ml distilled water.
Two procedures of isolation were followed. From the suspension described above, 0.1ml portion was inoculated onto each of 3 replicate plates; 30 ml of medium were then poured onto each plate and thoroughly mixed with the inoculum. In the second procedure, particles of experimental material were plated on each medium in Petri dishes. Incubation temperatures in the laboratory were similar to the ambient temperatures of the processing site and the compost heaps. Pure cultures were obtained for microscopic identification.

### Isolation and identification of bacteria

Biochemical characterization and identification of various bacterial isolates were carried out according to the methods of Holding and Colle (1971) and Buchanan and Gibbons (1974).

### Isolation and identification of fungi

The several inoculation procedures used included: (i) Inoculation of 0.1 ml portions of the suspension was made onto 3 replicate plates; 30 ml of mycological agar (Sigma) was poured onto each plate and thoroughly mixed with inoculum and 0.5 ml of streptomycin (60 ugml$^{-1}$). (ii) Plating of particles of experimental material onto mycological agar. (iii) The particles which were conspicuosly rich in mycelia were examined under a microscope, the fungal hyphae picked up with a sterile needle and plated onto mycological agar. Identification procedures of Barnett (1960) and Gilman (1957) were followed.

## RESULTS AND DISCUSSION

The nature and population size of microorganisms in any composting heap depend very much on a number of factors,

**Table 1.** Nutrient composition of urban refuse and poultry manure before composting.

| Sample | %C | %N | %C/N | %$No_3N$ | %$NH_4N$ | %P | %K | %Ca | %Mg | Fe (Mg/kg) | Zn (Mg/kg) | Mn (Mg/kg) | Cu (Mg/kg) | Ca (Mg/kg) | Pb (Mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Refuse | 48 | 1.20 | 40 | ND | 0.03 | 0.3 | 220 | 0.31 | 0.24 | 51.2 | 12.50 | 2.50 | 2.5 | ND | 2.5 |
| Poultry | 14 | 3.9 | 3.6 | 0.07 | 0.45 | 1.39 | 274 | 1.39 | 0.35 | 0.19 | 9 | 210 | 35 | 4 | ND |

ND = Not Detectable.

one of which is temperature. While large heaps lead to the generation of high temperature, small heaps generate low temperature. In this study, however, a relatively small heap of wastes consisting of urban refuse and poultry manure (nutrient composition in Table 1) composted in the 250 L pot using PACT gave relatively high temperature. Figure 1 shows that a peak of about 70$^oC$ was attained in the first week even when only about 200 kg waste (wet weight) was composted. The plastic pot used conserved the heat generated by the microorganisms. It was not necessary to turn the wastes because preliminary composting using this method showed that there was no reheat after compost turning. The compost so formed had good nutrient composition (Table 2). This was not the case in the pit composting method where waste turning resulted in constant heat regeneration until about 5 months later when the temperature became low and stability attained. The pH of waste mixture in this study remained fairly constant both in the pot and in the pit (Figure 2).

**Table 2.** Nutrient composition of compost obtained from sorted urban refuse and poultry manure subjected to passive aeration composting technique in a pot (in the preliminary investigation).

| Properties | Values |
|---|---|
| %C | 25.0 |
| %N | 1.75 |
| C/N ratio | 14.70 |
| $No^3$-N (%) | ND |
| $NH_4$-N(%) | 0.03 |
| P (ditto) | 0.70 |
| K | 1.25 |
| Ca | 1.47 |
| Mg | 0.19 |
| Fe | 42.0 |
| Zn ($mgkg^{-1}$) | 0.90 |
| Mg | 1.70 |
| Cu | 0.52 |
| Cd | 0.02 |
| Pb | 0.07 |

The microorganisms identified at the 3 stages of temperature are listed in Tables 3 and 4. In Table 3 , the bacteria and actinomycetes isolated at mesophilic, thermophilic and cooling down stages in the pot and pit indicated that there were greater microbial diversity at the mesophilic stage of decomposition than at the thermophilic stage. The bacterial isolates obtained at mesophilic temperature included *Bacillus* species, some faecal

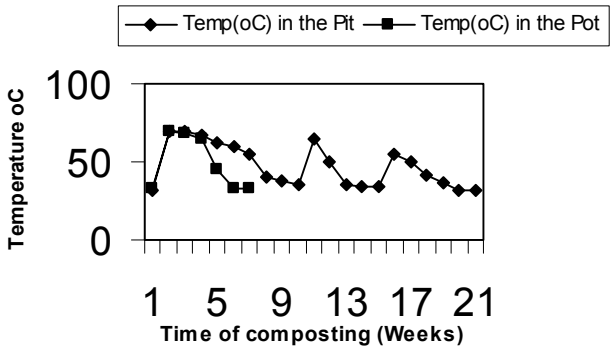


**Figure 1.** Influence of temperature on composting urban waste.

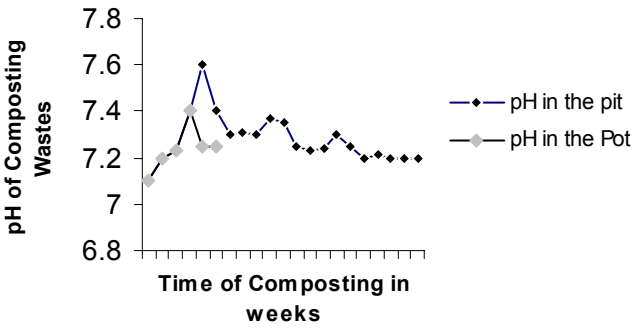


**Figure 2.** Influence of pH on composting urban waste.

coliforms, *Pseudomonas, Streptococcus, Proteus* and *Seratia*. Also isolated were *Streptomyces* and *Actinomyces* species, and *Streptosporangium*. However, *Bacillus* spp isolated at the mesophilic stage were again found at the thermophilic stage. These organisms along with *Seratia* sp may have been active at this stage and hence carried the process to the cooling down stage. They also persisted during the cooling down stage along with others. Other microorganisms not found at this elevated temperature might have been adversely affected by the thermal effect of the heat generated by microbial activities. At the cooling-down stage, occurrence of *Bacillus* spp was again observed, while the actinomyces isolated at the mesophilic stage recolonised the final compost. These microorganisms might have remained dormant at the thermophilic stage only to regrow at lower temperature.

Bacterial and actinomycetes succession in the wastes piled in pit and that of pot was somewhat similar though some microorganisms found in the pit were not isolated in

**Table 3.** Bacterial and actinomycete isolates at mesophilic, themophilic and cooling down stages of composting using Passive Aeration Technique (in pot) and the conventional pit method.

| Bacterial and actinomycete Isolates | Isolates obtd b/w 30-39$^0$c (Mesophilic stage) | | Isolates obtd b/w 40-60$^0$c (Thermophilic stage) | | Microorganisms obtained at the croling down stage | |
|---|---|---|---|---|---|---|
| | In Pot | In Pit | In Pot | In pit | In Pot | In Pit |
| **Bacteria** | | | | | | |
| *Bacillus sp 1* | P | P | P | P | P | P |
| *Bacillus sp II* | P | A | P | A | P | A |
| *Escherichia sp* | P | P | A | A | A | A |
| *Enterobacter sp* | P | P | A | A | A | A |
| *Klebsiella sp* | P | P | A | A | A | A |
| *Pseudomonas* | P | P | A | A | A | P |
| *Steptococcus sp I* | P | P | A | A | P | P |
| *Slreptococcus sp II* | P | A | A | A | A | A |
| *Methylomonas sp* | A | P | A | P | A | P |
| *Proteus sp* | P | P | A | A | A | P |
| *Seratia sp* | P | P | P | P | P | P |
| *Azomonas sp* | A | P | A | A | A | P |
| **Actinomycete** | | | | | | |
| *Streptomyces sp* | P | P | A | A | P | P |
| *Actinomyces sp* | P | P | A | A | P | P |
| *Streptosporangium* | A | P | A | P | A | P |

A = Absent
P = Present

**Table 4.** Fungal isolates a mesophilic thermophilic and cooling down stages of composting in pot and pit.

| Fungal Isolates | Isolates Obtained b/w30-39$^o$C (mesophilic stage) | | Isolates Obtained b/w 40-60$^o$c (thermophilic stage) | | Microorganisins obtained at the cooling down stage | |
|---|---|---|---|---|---|---|
| | Pot | Pit | Pot | Pit | Pot | Pit |
| *Aspergillis sp I* | P | P | A | P | A | P |
| *Aspergillus sp II* | P | A | A | A | P | A |
| *Fusarium sp* | P | P | A | P | P | P |
| *Penicillum sp I* | P | P | A | P | A | P |
| *Cladosporium sp* | P | P | A | A | A | P |
| *Humicola sp* | P | P | P | A | A | A |
| *Mycotypha sp* | P | P | P | P | P | P |
| *Scopulariopsis sp* | P | P | P | A | P | A |
| *Coprinus sp* | P | P | A | A | P | P |
| *Cephalosporium sp.* | P | P | P | A | P | P |
| *Rhizopus sp* | A | P | A | A | A | A |
| *Trichothecuim sp* | A | P | A | P | A | P |

A = Absent
P = Present

the pot possibly because some of the soil indigenous microflora may have entered the wastes through soil-waste contact. *Methylomonas* spp was prominent at the three temperature levels. The presence might be due to the existence of pockets of anaerobic sites in the degrading wastes. Similarly, *Streptosporangium* spp was found at the 3 temperature stages. The reason might be due to its ability to easily reproduce itself through spores and its hyphae. In table 4, *Aspergillus, Fusarium, Penicillium, Cladosporium, Cephalosporium, Humicola, Mycotypha* and *Scopulariosis* sp are the fungi isolated. All except *Aspergillus* sp II in pit, *Rhizopus* and *Trichothecium* sp in pot were isolated at the mesophilic stage.

The diversity of fungi at thermophilic stage was markedly reduced. Most prominent of the fungi isolated at the cooling down stage were *Fusarium* and *Mycotypha* spp. *Coprinus* sp was the most prominent in the pit. Generally there was greater microbial diversity at mesophilic stage, which

**Table 5.** Nutrient composition of compost produced using the passive aeration and pit composting techniques.

| Composting technique | %C | %N | %C/N | %$NO_3$N | %$NH_4$N | %P | %K | %Ca | %Mg | Fe (Mg/kg) | Zn (Mg/kg) | Mn (Mg/kg) | Cu (Mg/kg) | Cd (Mg/kg) | Pb (Mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pot | 27.70 | 1.90 | 15.00 | ND | 0.05 | 0.80 | 1.77 | 1.50 | 0.17 | 47.00 | 0.70 | 1.00 | 0.23 | ND | 0.06 |
| Pit | 35.20 | 1.00 | 35.00 | ND | 0.06 | 0.30 | 1.20 | 1.30 | 0.14 | 27.40 | 0.50 | 0.75 | 0.21 | ND | 0.02 |

ND = Not Detectable.

becomes reduced at the thermophilic temperature. When the temperature became suitable at cooling down stage, some of these organisms grow again from spores.

Alexander (1977) observed that the microbial activities are directly related to the availability of energy sources and inorganic nutrients required for their growth. Chang and Hudson (1967) observed in a composting study that some heterotrophic microrganisms had developed profusely for about 2 days at the beginning of composting, raising the temperatures to the levels where thermophiles, such as the non-cellulotic *Mucor pusillus* and *Thermomyces lanuginosus*, and the thermo-tolerant *Aspergillus fumigatus* were stimulated to grow up to 55-60$^{o}$C above which thermophilous actinomycete and bacteria took over raising the temperature to its peak. At the peak, the investigators noted that the number of actinomycetes and bacteria declined and thermophilous fungi recolonized from cooler and more peripheral areas and maintained the temperature above 40$^{o}$C, during the prolonged cooling down stage. Hudson(1986) identified this stage as a period of maximum activity of the markedly cellulolytic *Chaetomium thermophile* and *Humicola insolens* and also of the non-cellulolytic *Thermomyces lanuginosus*. The author noted that as the temperatures finally dropped below 40$^{o}$C, several mesophiles were observed to have colonized the compost, the most notable of which was the thermo-tolerant *Coprinus cinereus,* which are capable of utilizing both cellulose and lignin. The other organism identified by Hudson (1986) was *M. pusillus* which occurred in early phases of composting. Mishra et al. (1982) reported that *Chaetomium globosum*, *Fusarium solani, Paecilomyces varioti* and *Penicillium chrysogenum* were common in compost piles and this might be attributed to their ability to produce some cellulases.

In the passive aeration composting technique used in this study, some of these microorganisms were not found. The reason might mainly be due to the disimilarity in the method of composting used and the difference in the raw wastes used by different authors. Nutrient compositions of the composts obtained from the 2 techniques are shown in Table 5. Compost obtained from the pot contained higher concentrations of macro and micronutrients. The C/N ratio of compost in the pot was lower than the C/N ratio obtained from the pit.

In general, it was found in the study that the piling-up method took longer time to complete. A number of microbial contaminants from the soil were found while the process was laborious. Degradation was not complete inspite of the longer composting period of 5 months. From this study, we observed that if microbial succession is allowed to proceed in its natural course in an environment characterised by adequate nutrients, moisture, air, and temperature, biodegradation will also proceed naturally with one group of organisms using the product of another group as substrates leading to near complete degradation.

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