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Rotary Drum Composting of Mixed Organic Waste based on Different C/N Ratios

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ABSTRACT

Effects of the carbon to nitrogen (C/N ratio) on the composting of organic waste were examined by measuring changes in temperature, pH, EC, moisture content, TOC, total nitrogen, total phosphorus, VFAs, coliforms, BOD, COD. Time courses of the above values differed substantially between two experimental runs of different C/N ratio: 22 (Run A) and 30 (Run B). It was observed that time courses for getting matured compost were quite different in both cases. Run B containing larger amount of food and vegetable waste showed a slower rise in temperature, lower maximum temperature and shorter thermophilic phase than Run A. On the other hand, it also resulted in higher increase in pH, higher content of moisture, ammonical nitrogen and total organic carbon throughout the composting period. Since, the evolution of ammonical nitrogen is associated with the degradation of proteins. Run A showed 0.82 g/kg increase of total phosphorus compare to 0.57 g/kg in Run B.

Biological parameters including COD (454 mg/l), BOD (107 mg/l), fecal coliform (5 × 10^2 *bacteria/g), fecal streptococci (5 ×*10^3 *bacteria/g) observed in Run A while COD (538 mg/l), BOD (342 mg/l), fecal coliform (9.3 ×* 10^6 *bacteria/g), fecal streptococci (4.3 ×* 10^5 *bacteria/g) observed in Run B, indicated that Run A achieved maturity after 20 days of composting. Run B showed a relatively higher BOD/COD ratio and coliforms, indicating its immature nature with more than 4% of total nitrogen due to larger amount of food and vegetable waste. Therefore, to obtain the matured compost in a rotary drum at an initial C/N of 22 required 20 days compare to an initial C/N of 30.*

Keywords*: Decentralized composting, Rotary drum, C/N ratio, Mixed organic waste, Temperature, Coliform, BOD/COD ratio.*

1.0 INTRODUCTION

Even though Rotary drum composting is a proven-technology that can be applied on the spot, there are many aspects that should be improved in the performance of current composting facilities. In the composting of organic wastes, the chemical nature of substrate is a key factor in determining the progress of composting process. The quantity and the balance of nutrients, as well as degree of availability of nutrients to various microorganisms are essential. For achieving good quality compost, environmental factors such as temperature, aeration, moisture and nutrients should be appropriately controlled (Gotaas, 1956).

The effects on composting at various initial C/N ratios on the decomposition, hygienization and maturity process are not well understood. Hence, the aim of the study was to investigate the changes in physicochemical and biological properties of composting of various organic wastes i.e. cattle manure, vegetable wastes, paper waste and sawdust at an initial C/N ratio of 22 and 30 in a Rotary drum type composter.

2.0 MATERIALS AND METHODS

2.1 Feedstock Material

Cattle manure, mixed green vegetables waste (uncooked), food waste (cooked), paper waste and sawdust from various places of Roorkee city, India. Prior to composting, the maximum particle size in the mixed waste was resticted to 1 cm in order to provide better aeration and moisture control. An initial C/N ratio of 22 was brought about by mixing cattle manure, mixed green vegetables and sawdust in a 2.5:2:1 ratio on wet mass basis. By mixing of cattle manure, mixed green vegetables, food waste, paper waste and sawdust used for adjusting an initial C/N ratio of 30. The composition of wastes of Run A and B of C/N ratio of 22 and 30 respectively are detailed in Table 1.

Table 1. Characteristics of Material Mix

Run	*Mixing weight (Kg)*						*Initial weight (Kg)*	*Moisture content (%)*	*C/N ratio*
	Cattle manure	*Food waste (Cooked)*	*Vegetable waste (Uncooked)*	*Paper waste*	*Saw dust*	*Manure*			
A	25	0	20	0	10	5	60	61.12	21.577
B	18	25	10	4	10	5	69	64.93	29.6053

2.2 Rotary Drum Composter Design

In order to study the compost dynamics, a Rotary drum composter of 250 L capacity was used. The main unit of the composter, i.e. the drum is of 0.92 m in length and 0.9 m in diameter, made up of a 4 mm thick metal sheet. The inner side of the drum is covered by anti-corrosive coating. The drum is mounted on four rubber rollers attached to metal stand and the drum is rotated manually. In order to provide the appropriate mixing of wastes, 40 mm angles are welded longitudinally inside the drum. In addition to that, two adjacent holes are made on top of the drum to drain excess water. The shredded mixed organic waste is loaded into the drum by the means of plastic container and filled up to 70% of the total volume. Aerobic conditions are maintained by opening up both half side doors of the drum after four rotations are provided manually on a daily basis, which ensure proper mixing and aeration.

2.3 Measurement Techniques

Each test involved six grab samples of compost matter from the reactor at six different locations. Random samples were obtained from several different points, mostly at the mid span and ends of the composter. Triplicates samples were collected and stored at 4^{o}C immediately till analysis. Temperature was monitored using a digital thermometer throughout the composting period. Sub-samples were air dried, ground to pass to 0.2-mm sieve and stored for further analysis. Each sample was analyzed for the following parameters: moisture content, pH, electrical conductivity (EC), total Kjeldahl nitrogen (TKN), NH_4^+-N and NO_3^--N, Total Organic Carbon (TOC), total phosphorus, Volatile Fatty Acids (VFAs) (water soluble) including acetic acid, formic acid, butyric acid, propionic acid and total coliforms, fecal streptococci, fecal coliforms, BOD and COD.

3.0 RESULT AND DISCUSSION

3.1 Temperature

Temperature observations were taken at three different locations in the composter; i.e. at its center and at two ends. A graph showing the variation of temperature of composting material with time is illustrated in Figure 1(a). The mesophilic, thermophilic, cooling and curing stages are clearly depicted. In Run A, the initial temperature was 24.4^{o}C and increased up to 60^{o}C and entered the thermophilic phase on day 3 of composting, indicating quick establishment of microbial activities in the composter. The longer thermophilic phase as well as the higher rise in temperature in the beginning of composting was attributed to sufficient supply of carbon source. Further a cooling period was observed till the seventh day, and consequently a maturation period prolonged up to fifteenth day. However, Run B required 5 days, a comparative longer time, to reach a maximum temperature of only 50^{o}C less than Run A. This was due to high initial C/N, which did not provide a favorable condition for the growth and biological activity of microorganism.

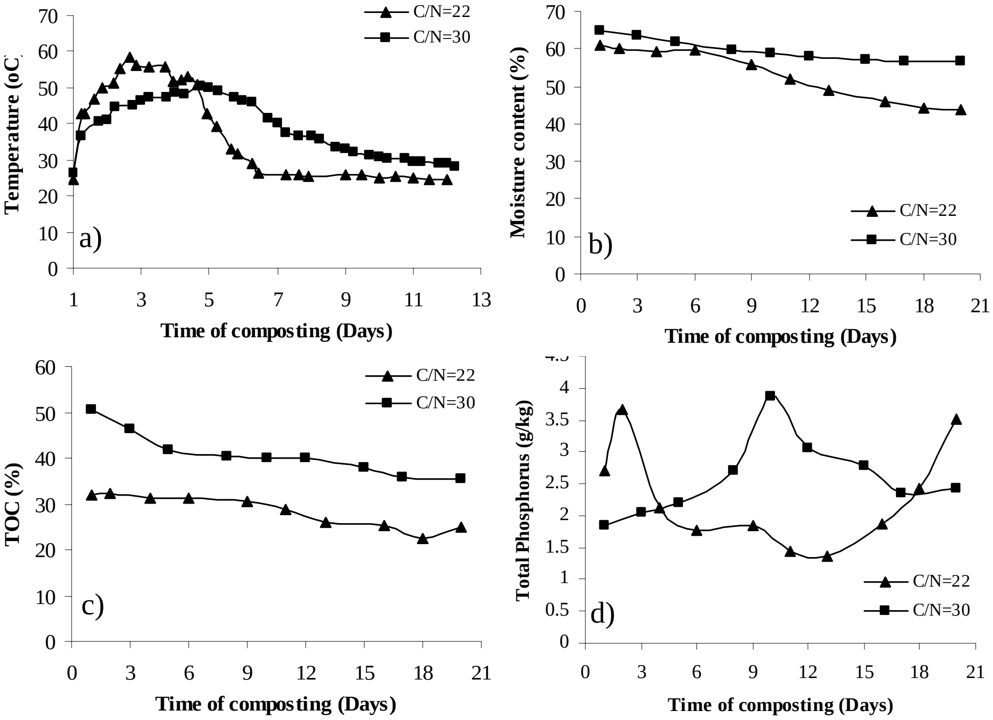

Figure 1 Temperature, Moisture, TOC and Total Phosphorus Over Composting Period

3.2 Moisture Content

Moisture loss during the composting process can be viewed as an index of decomposition rate, since the heat generation which accompanies decomposition drives vaporization (Liao, 1996). In the Run A, moisture content at the beginning was 61% and reduced to 44% within 20 days (Figure 1(b)). During the initial 12 days of composting, the moisture content was within an acceptable range of 50% to 65%. At the beginning moisture content was 65% in Run B containing larger amount of food/vegetable waste and reduced to 56%, which was within an acceptable range. Lower moisture loss (9%) observed in Run B compare to 17% loss in Run A as a result of high rise in temperature and longer thermophilic phase. The difference in moisture content in the top and bottom portions of the composter in the both cases was around 2-4%, implying uniformity achieved by rotation. The leachete formation wasn't observed during the composting period. A small drop of moisture content was also observed at the end as upper part was exposed to the environment.

3.3 Carbon Decomposition

Change in the total organic carbon content during the composting period is detailed in Figure 1(c). The content of organic carbon decreased as the decomposition progressed. Initially, the amount of total organic carbon were 31.90% and 50.4% which then reduced to 22.27% and 35.29%, respectively in Run A and Run B. there was no significant difference in the loss of total organic carbon between the two different C/N treatments. Around 30% of the available carbon in both Runs was utilized by micro-organism as a source of energy.

3.4 Total Phosphorus

Phosphorus in organic materials is released by a mineralization process involving micro-organisms. The evolution of total P (organic and inorganic) in Run A shows a gradual decrease in an initial 12 days, an obvious recovery subsequently due to the net loss of dry mass (Huage et al., 2004). The increase of total P in Run B observed upto 10 days and a decrease until the end of composting as observed by Zhange et al., (2006). The loss of total phosphorus during composting period is probably due to the mineralization of organic phosphorus and the consumption by microbes (Huang 2004). The final total P of Run A was higher than that of Run B, indicates the higher microbial activities during Run A resulting more mineralization (Figure 1(d)).

Inorganic phosphorus is negatively charged in most soils. Because of its particular chemistry, phosphorus reacts readily with positively charged iron (Fe), aluminum (Al), and calcium (Ca) ions to form relatively insoluble substances. When this occurs, the phosphorus is considered fixed or tied up. In this regard, phosphorus does not behave like nitrate (NO_3^-), which also has a negative charge but does not form insoluble complexes.

3.5 Nitrogen Dynamics

Figure 2 shows the time course of the total nitrogen (N_T) consisting of the inorganic forms of nitrogen (ammonium (NH_4-N), nitrate (NO_3-N)) and organic nitrogen (N_{org}). Total nitrogen contents in both Runs increased after 20 days of composting period, due to the net loss of dry mass in terms of carbon dioxide, as well as the water loss by evaporation caused by heat evolved during oxidization of organic matter (Fang et al., 1999b, Haung et al., 2004). Nitrogen fixing bacteria might also have contributed to the increase in N_T in the later stage of composting (Bishop et al., 1983). Run B contained significantly higher N_T (4.34%) than Run A (2.10%) throughout composting because of the higher amount of food/vegetable waste used in the experiment.

Both N_T and N_{org} behaved in a similar manner in both Runs as observed by Sanchez-Monedero et al. (2001). The N_{org} decreased due to the ammonification of N_{org} to NH_4-N by the fourth day and eighth day in Run A and B respectively, A further increase in the N_{org} can be attributed as a consequence of strong degradation of organic carbon compounds (Tiquia and Tam, 2000). The N_{org} was either mineralized into NH_4-N, which vaporized or was assimilated into by the microorganism in the compost (Morisaki et al., 1989). Higher concentration of N_{org} in the Run B indicated that more compounds were synthesized in the Run B compare to Run A with an initial C/N of 22.

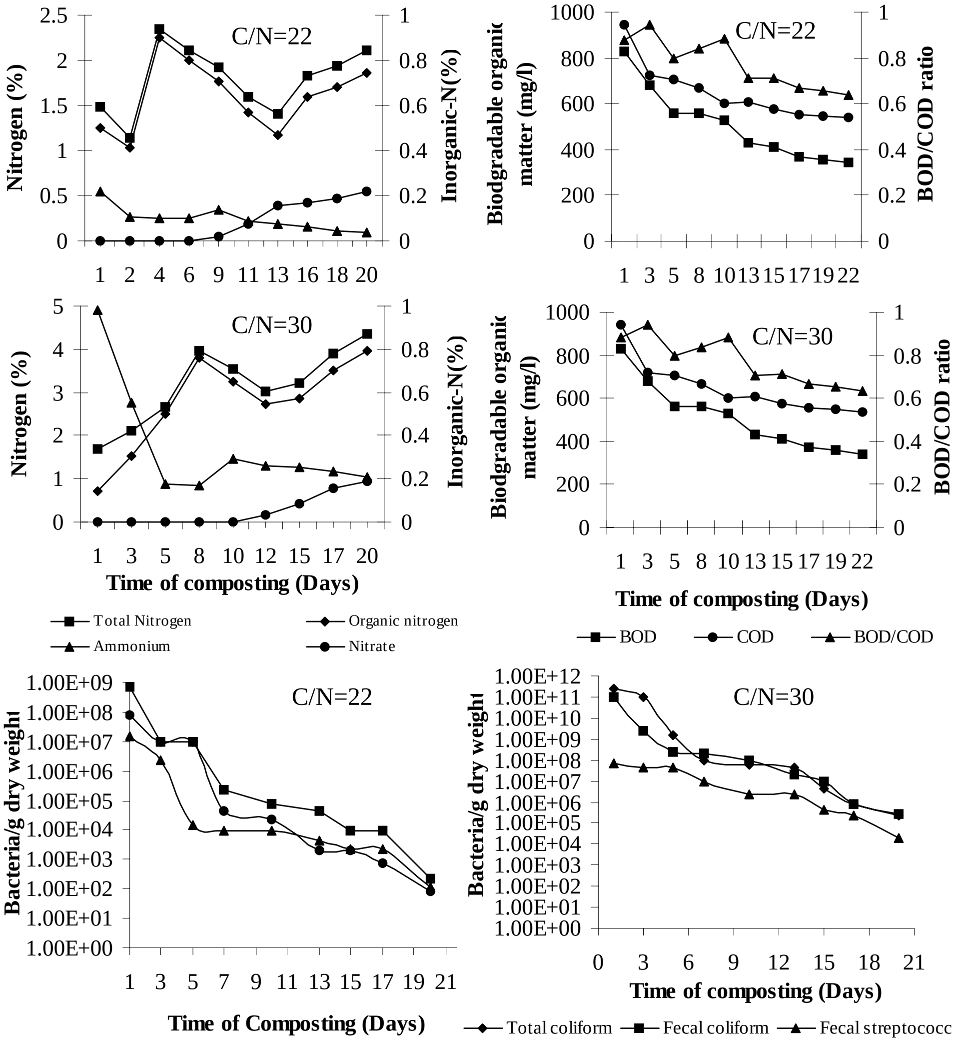

Figure 2 Nitrogen Dynamics, Coliform, BOD and COD Over Composting Period

The changes in concentration of NH_4-N and NO_3-N in the both Run followed the typical trends for this inorganic form of nitrogen during rotary drum composting. During the first 5 days of composting, NH_4-N concentration decreased significantly form 0.22% to 0.09% and 0.98% to 0.17%, increased slightly by the ninth day and tenth day and then stabilized at around 0.036% and 0.2% in Run A and B respectively by the end of the composting. The slight increase in NH_4-N concentration could be due to the conversion of N_{org} to NH_4-N through volatilization and immobilization by microorganism (Haung et al., 2004), which also indicates a decrease in N_{org} concentration at this stage of composting. It has been noted that the absence of or decrease in NH_4-N is an indicator of both good composting and maturation process (Hirai et al., 1983). An NH_4-N content of 0.4% was recommended as the maximum content in mature compost (Zucconi et al., 1981). Therefore, both Runs reached maturity after 20 days, but Run A showed more maturity compare to Run B.

The rapid decrease in NH_4-N concentration during composting did not coincide with a similar increase in the NO_3-N concentration. Nitrate was almost absent at the beginning, remained unchanged during the first 6 and 10 days in Run A and B respectively and occurred only when temperature fell below 40^oC. The high temperature and excessive amount of ammonia inhibited the activity and the growth of nitrifying bacteria in the thermophilic phase (Morisaki et al., 1989). This seems to suggest that N_{org} mineralization is the limiting step in nitrification since such mineralization was scant during the last phase of composting, when the supply of ammonium available to the nitrifying bacteria would have been reduced (Sanchez-Monedero et al., 2001). No significant difference in NO_3-N content between the two Runs was noted.

3.6 BOD and COD

The percentage of readily biodegradable organic matter is believed to be an important aspect of compost quality (Bernal et al., 1997). Composting process occurs until the total amount of biodegradable organic material is stabilized, which is odor and pathogen free and also a poor breeding substrate for flies and other insects. Even if the compost is stable, care should be taken for its application to soil for crop use as the biological processes continue which can strip the soil of its nutrients. (Wang et al, 2004).

The aerobic condition brought about by the respiration of biodegradable organic matter in the compost, is measured as BOD and COD. As the biological organic content is diminished, BOD and COD are decreased, resulting in decreased emission of carbon dioxide, ultimately indicating stabilization of the compost. BOD and COD values decreased from 580 to 107 mg/l (5.8 to 1.07 mg/g) and 1512 to 458 mg/l (15.12 to 4.58 mg/g) in Run a, while in Run B 830 to 342 mg/l (8.3 to 3.42 mg/g) and 943 to 539 mg/l (9.43 to 5.39 mg/g) respectively within 22 days.

Figure 2 shows that the rate of decrease of BOD is lower than that of COD in Run A. Correspondingly, BOD/COD ratio decreased from maximum 0.94 at fifth day to 0.23 by the end. While in Run B BOD/COD ratio decreased from maximum 0.94 at third day to 0.63, lower than Run A. This final decrease in the BOD/COD ratio indicates the stabilization of the compost as only the non-biodegradable parts remains. Results indicated that more degradation of organic matters taken place in Run A compare to Run B within the composting period of 20 days.

3.7 Coliforms

The presence of coliform bacteria is often used as an indicator of overall the sanitary quality of the compost. For compost hygienization, the recommended fecal coliforms (FC) and fecal streptococci

(FS) densities are 5 X 10^2 bacteria/g and 5 × 10^3 respectively (Vuorinen et al., 1997). The average number of coliform bacteria observed in Run B is more than Run A containing larger amount of food and vegetable waste. The trend with time showing in Figure 2, total coliforms levels declined significantly in the early stages of composting. The decrease was presumably the result of the high temperature and unfavorable conditions established during the thermophilic phase (Hassen et al., 2001).

At the beginning of the composting process the average number of fecal coliforms considerably decreased, respectively, from 7.5×10^8 to 7.5×10^2 and 9.3×10^{10} to 2.5×10^5 bacteria/g correspondingly in Run A and B. Fecal streptococci are generally considered to be the best indicators of fecal pollution as they are more resistible to unusual environmental conditions. The fecal streptococci population observed a distinct decrease from 1.5×10^7 to 2.3×10^3 and 7.5×10^7 to 2.1×10^4, respectively in Run A and B during the composting period. The percentage reduction of fecal coliforms and fecal streptococci in Run A is higher comparing to Run B. The numbers of fecal coliforms and fecal streptococci are to low at the end in Run A compare to Run B, indicates more hygiene compost in Run A within 20 days. Run A compost could be directly apply to soil without any maturation.

4.0 CONCLUSIONS

Composting for the waste with C/N ratio of 22 (Run A) yields 2.1% N_T & 3.5% total phosphorus after 20 days. Additionally, the compost was hygienically safe and quite mature with 7.5×10^2 of fecal coliform, 2.3×10^3 of fecal streptococci and BOD/COD ratio of 0.23. However, in case of C/N ratio of 30 (Run B), compost yields 4.35% of N_T and 2.3 % after 20 days, but, it had higher fecal coliforms 2.5 x 10^5 bacteria/g, fecal streptococci 2.1×10^4 bacteria/g, high TOC, NH4-N and BOD/COD ratio of 0.6 rendered it hygienically unsafe and immature.

The electrical conductivities of final composts in both runs were very low and are considered as a soil fertilizer with good quality according to the standards to ensure safe application of compost. During the thermophilic phase, the temperature remained above 50^oC in both Runs satisfying the regularity requirement for the destruction of pathogens viz. salmonella sp. and shigella sp. within 5-6 days. The negligible amount of VFAs concentration observed in both composting Runs indicated the full aerobic condition during the composting period.

Therefore, it can be supposed that Rotary Drum composting of mixed organic waste at initial C/N ratio of 30 (Run 2) can produce quality compost, but it would require a composting period of more than 20 days.

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