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,Enzyme Activities and Microbial Dynamics During the Rapid Composting of Municipal Solid Waste: A Compost Maturity Study

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Abstract:

An investigation was carried out in the laboratory scale basis to find out the microbial dynamics and enzyme activities during rapid composting of municipal solid waste (MSW). The effect of various additives and Various treatments such as aeration (A),glucose (G) acetic acid (AA) and application of cellulolytic microbial (M) inoculum (Phanerochaete chrysosporium and Trichoderma reesei) were used to facilitate the decomposition of MSW. The result of the investigation revealed that the degradation of organic substrates were quick (within 10– 14 days) Whereas, the normal composting took more than 30 days to attain C/N ratio of below 20. A perusal of results showed that addition of additives specific degradation profiles of various labile substrates contained in organic waste.

Keywords:
Aeration; Enzyme activities; Municipal solid waste; Compost; Additives.

Introduction:

Solid is of concern, especially in developing countries like India, China etc. Large waste management has become a major environmental issue in India. India and China are facing a serious solid waste problem, which is further aggravated by rapid urbanization (Ahmed and Jamwal 2000, Hong et. al., 1996). With rising urbanization, change in life style, food habits, the socio-economic status and cultural habits, prevailing climate, location, urban structure, population density, extent of non-residential activities (CPCB, 2000), About 0.1 million tones of MSW is generated in India every day, approximately 36.5 million annually. The per capita MSW generated daily in India ranges from about 100 gram in small towns to 500 gram in large towns (TERI, 2000). The MSW generated in India comprises of 30 per cent to 45 per cent of organic matter (NEERI, 1996). The enzymes released by the microorganisms during composting breakdown several organic compounds characterized by a complex structure, finally leading to the solubilisation of simple water soluble compounds (Benitez et al., 1999). Characterizing and quantifying enzymatic activities during composting can reflect the dynamics of the composting process in terms of the decomposition of organic matter and nitrogen transformations, and may provide information about the maturity of composted products (Tiquia, 2002).

In addition, on the basis of the well demonstrated relationship between enzymatic activity and quantity and quality of organic matter it could also give information on compost stability (Garcia et al., 1993), defined as the degree of decomposition of the readily bio-degradable organic matter (Lasaridi and Stentiford, 1998). Moreover, enzymatic activity determination, in contrast to most of the analytical techniques used for compost stability evaluation, is easy, fast and relatively in expensive (Mondini et al., 2004).

In view of the above, the present investigation aims at Enzymatic activicty in composting of municipal solid waste through facilitated aeration, addition of chemical agents and cellulolytic microorganisms, besides understanding the efficiency of composting process using microbial dynamics as the yard stick.

Material and methods:

Rapid composting experiments were carried out in specially designed composters of 5 Kg capacity. Municipal solid waste was collected from Nagpur Municipal Corporation, Nagpur, Lignocellulosic waste material collection from Sevadal Mahila Mahavidyalaya Campus, and brought to the laboratory in safe containers. After initial screening, the waste materials were air-dried and segregated for other inorganic materials such as glasses, plastics and other inert etc. The materials were oven dried at 60degree C for 2 days and shredded to a size of 0.5–1.5 mm for further processing

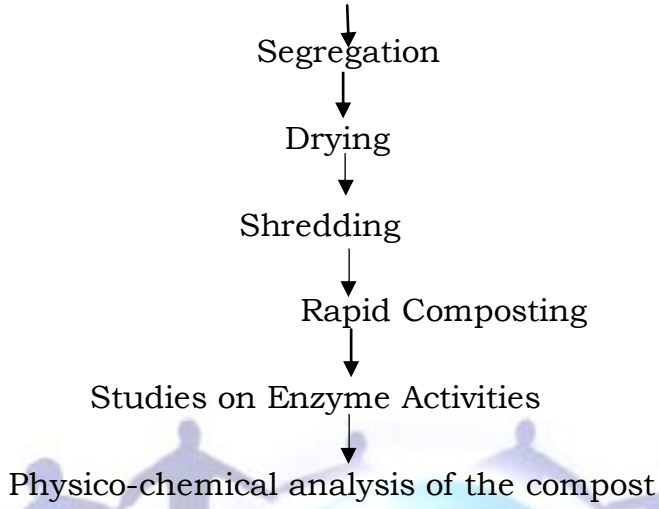
The materials were sun dried for 3 days and crush by pulvariser to a size 10 to 25 mm. Vegetable waste was shredded in the range of 25 mm to 75 mm, (Tchobanoglous, G. et. al, 1993). The particle size of a greater part of green mash such as vegetable waste should not be less then 50mm (Diaz et al., 2002).

Rapid and Normal Composting of MSW Experiments Methodology.

2 Kg of the dried and shredded material was taken in a tray, sprinkled with water and added with chemical and biological agents such as glucose (G) (10gms/2 kg of material), acetic acid (AA) (35-40 ml/ 2 kg of material for a pH of 5.5) and cellulolytic microbial inoculum (M) (100 ml of mixed inoculum having both P. chrysosporium ($1.5X10^6$ CFU/ml) and Trichoderma reesie (0.60 - 10^6CFU/ml), separately in three different composters. Composting without aeration and addition of chemicals and microbial inoculum represented normal composting process. All the treatments were maintained with 55 % of moisture which is inclusive of the water used while making dilutions for the addition of glucose, acetic acid and inoculum. Thus, a total of four composting experiments via. NC, Aeration + glucose (A + G), Aeration + glucose + acetic acid (A + G + AA), Aeration + glucose + acetic acid + microbial inoculum (A + G + AA +M) were started at the same time and continued for 21 days. The experimental set up was kept in the laboratory with an average room

temperature of 17 ± 4^{0}C and relative humidity as 60%.during the Composting periods.

Municipal Solid Waste Collection From Vegetable Market and MSW Dumping Site at Bhandiwadi Nagpur



Estimation of Microbial Enzyme Activities.

Selected enzymatic activities were determined in fresh and sieved samples (1 gm) of compost. The amylase activity was assayed at pH 5.2 employing sodium acetate-acetic acid buffer with 8 % soluble starch as substrate following the method of Nelson- Somogyi (Somogyi, 1952). Alkaline phosphatase was estimated according to Alef et al.,(1995). Protease activity was quantified by measuring hydrolysis of casein using the method of Ladd and Butler (1972). The cellulase activity was determined using carboxy methyl cellulose as substrate (Alef and Nannipieri, 1995)

Physico-chemical analysis of the compost.

Samples were drawn from both rapid and normal composting experiments once in 2 days upto 21 days and were analysed for both physico-chemical and biological parameters. The chemical analysis of the samples were performed on air-dried (27^0 -29^0 C for 4 days) samples. The pH of the compost was determined in distilled water with a 1:10 (w/v) compost: water ratio. Changes in the temperature profile of during composting were recorded using a mercury thermometer kept permanently in the middle of the composters. The organic carbon content of the compost was estimated by combustion method (Nelson and Sommers, 1982) and total nitrogen by Kjeldahl method (Bremner and Mulvaney, 1982). The microbial (bacteria and fungi) biomass were assessed by counting the colony forming units (CFU) plated on a suitable media after incubation 37^{0}C. As per the Table 4.7 analytical methodology of the composting process.

Result and discussion:

The physico-chemical analysis of the raw MSW used for the experiment recorded 53.13% compostables with 44% moisture (adjusted to 58% for the experiment). The pH of the raw MSW was 7.6. The organic carbon content of the material was 45.60% with an initial C/N ratio of 33.53. The calorific value of the MSW was determined as 2400 Kcal/kg.

The changes in physico-chemical parameters during normal and rapid composting of MSW recorded showed interesting information. In the present investigation, an increase in the temperature was observed However, the rise in temperature proceeded much faster in case of RC than the NC experiments. A maximum of 41°C was recorded in case of A + G treatment on the 3rd day of experiment followed by A + G + AA + M and A + G + AA. Whereas, the NC experiments recorded an increase (30°C) in the temperature only during the 6–9 day period of composting. Temperature has been shown to be a critical determinant of composting efficiency (Finstein et al., 1986).

Data on the C/N ratio of the compost prepared through RC and NC experiments are given in Table 1. The results showed that reduction of C/N ratio in case of RC is better than that of NC. Within 21 days, the C/N ratio in case of RC mixture reduced to a minimum of 11.65 in A + G treatment followed by A + G + AA (12.44) and A + G + AA + M (14.67). Whereas, in the case of NC the reduction was 18.04. Another interesting observation is that though a maximum reduction of C/N ratio was observed at the last day (21st day) of the experiment, looking into the data, it is clear that irrespective of the treatment given, a maximum reduction in the C/N ratio happened only during the early (0–9 days) stage of composting, followed by a marginal decrease in the later days. The C/N ratio below 20 is indicative of acceptable compost maturity. It has been reported that during efficient composting, the C/N ratio is expected to decrease because of degradation of organic matter and mineralization (Margesin et al., 2006). Chanyasak et al. (1982) found a linear relation between the ratio of total organic carbon to total nitrogen and proposed that C/N ratio in water extracts of well matured compost should be 5–6. However, Hirari et al. (1983) The comparative decrease in C/N ratio of the rapid composting over the normal composting in the present investigation indicates the effectiveness of various treatments in facilitating the rapid degradation of organic materials.

Changes in microbial biomass.

Table 2 and Figs. 1 and 2 show the changes in microbial biomass during rapid composting of MSW. It was found that the bacterial biomass of RC experiment increased with time notably up to 15 days of composting followed by a marginal decrease. Among the various treatments of RC, A + G + AA had an overall increase in bacterial biomass followed by A + G + AA + M and A + G. The fungal biomass, on the other hand, showed a slight increase (upto 12–15

days) in RC excepting A + G + AA + M treatment, Comparing all the treatments of RC, the fungal biomass was higher in the case of A + G + AA + M, probably because of the initial addition of fungal cultures in this treatment. The fungal biomass in case of NC showed a steady increase with time.

Mostly, fungi are involved in the decomposition of cellulose, hemicellulose and lignin present in the organic matter. Among the RC experiments, the cellulase activity was found to be higher in A + G + AA + M. This could have attributed to the initial addition of fungal cultures (P. chrysosporium and T. reesei) in this treatment. Low cellulase activity at the beginning followed by an increase in the later stages of NC may be because of the insufficient growth of cellulolytic fungus during the early phase of composting Fig. 2, which grew further during the later phase with a consequent increase in cellulose activity. One more reason, which can be suggested for the increase, may be the reduction in C/N ratio in the later stages of normal composting, which allowed greater nitrogen availability (Ashbolt and Line, 1982) and favoring the growth of microbial biomass.

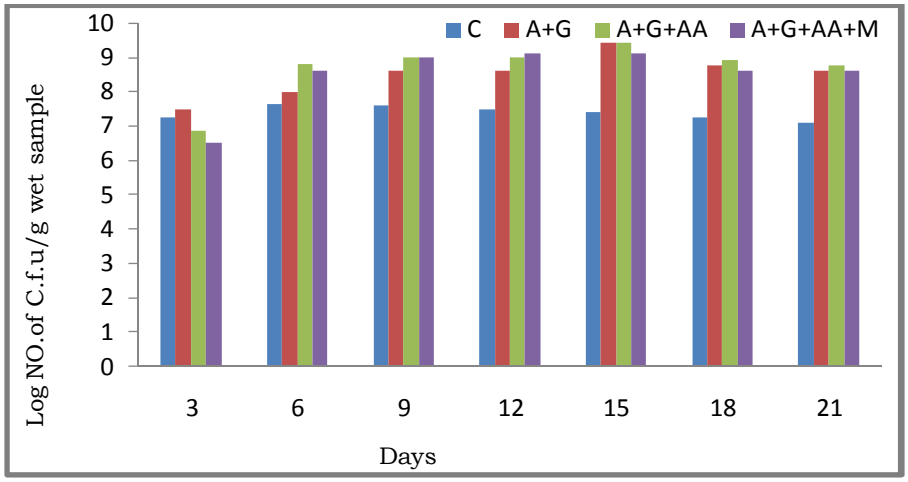
Table. 1- Changes in the C/N ratio during normal and rapid composting of MSW

	Treatments			
Days	**NC**	**A + G**	**A + G + AA**	**A + G + AA +M**
0	33.53 c	33.53 f	33.53 d	33.53 c
2	30.12 bc	28.66 e	28.37 c	26.57 b
6	26.54 ab	21.92 cd	18.34 b	18.43 a
9	23.29 ab	19.26 cd	18.55 b	17.50 a
12	22.13 a	18.31 bcd	17.39 ab	17.04 a
15	21.21 a	15.17 abc	15.63 ab	16.35 a
18	20.17 a	13.06 ab	14.44 ab	15.13 a
21	19.64 a	11.65 a	12.45 a	14.68 a

Means followed by a common letter are not significantly different at the 5% level by DMRT.

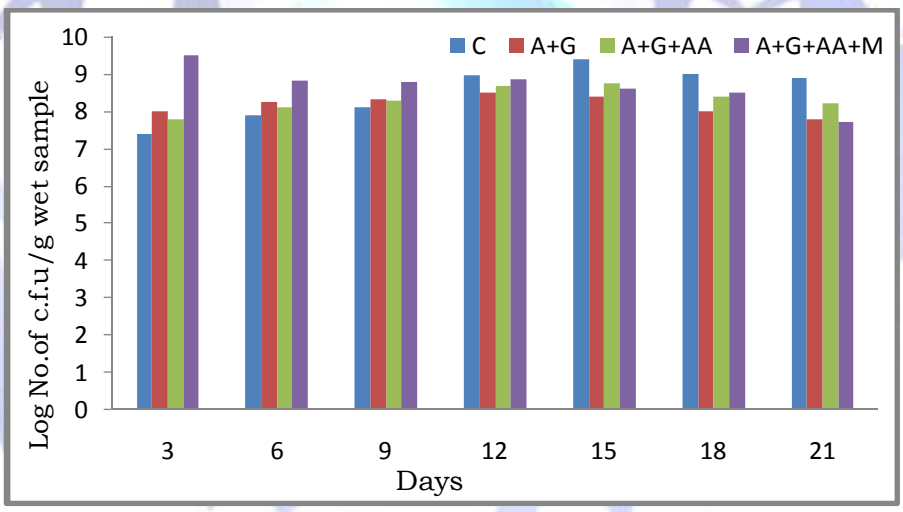
Table. 2- Changes in the bacterial and fungal biomass (Log. No. of c.f.u./g wet compost) during composting

Composting Time	Control		A+G+AA+M		A+G		A+G+AA	
	Bacteria	Fungal	Bacterial	Fungal	Bacterial	Fungal	Bacterial	Fungal
3	7.23	7.39	7.51	7.98	6.84	7.81	6.47	9.53
6	7.73	7.84	7.98	8.25	8.83	8.08	8.59	8.84
9	7.62	8.08	8.56	8.18	8.99	8.18	8.98	8.78
12	7.58	8.95	8.65	8.48	9.00	8.54	9.07	8.65
15	7.40	9.36	9.25	8.39	9.28	8.77	9.17	8.59
18	7.28	9.04	8.82	8.04	8.95	8.34	8.69	8.45
21	7.08	8.97	8.63	7.90	8.84	8.08	8.54	7.78



NC- Normal composting, A+G-Aeration+Glucose, A+G+AA-Aeration+Glucose+Acetic acid, A+G+AA+M-Aeration+Glucose+Aceticacid+Microorganism
Values are means of three replicates ± standard errors.

Figure. 1-Changes in the bacterial biomass during rapid and normal composting experiments



NC- Normal composting, A+G-Aeration+Glucose, A+G+AA-Aeration+Glucose+Acetic acid, A+G+AA+M-Aeration+Glucose+Aceticacid+Microorganism
Values are means of three replicates ± standard errors.

Figure. 2- Changes in the fungal biomass during rapid and normal composting experiments

Conclusions:

In the present waste management scenario, the biodegradable waste materials is rapidly increasing due to human activities as well as commercial activity so that it should be properly management by various activities. Composting process is one of the best options to manage the biodegradable waste materials. This study is apparent through on microbial dynamics and enzyme activities. On the other hand, different physico-chemical parameters

including C/N ratio assessed in the present investigation could not provide a clear understanding about the degradation profiles of various organic substrates as that of microbial dynamics and enzyme activities. The stability and maturity of compost is associated with the time of composting. it is checked with proper stability and maturity parameters like C/N ratio etc. In spite of the constant ambient temperature, temperature comes down at the end of the composting process.

Rapid composting using facilated aeration of composting process of using as raw materials included as VSW, agricultural waste, Cow dunk and Green waste and MSW in proper proposition. In rapid composting process, using Additives aided as a substitute for rapid degradation of composting process. In this composting process finished compost or mature compost was gating in 21 ± 4 days.

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