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Effect of Temperature, Dry Solids and C/N Ratio on Vermicomposting of Waste Activated Sludge

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Abstract: The effect of temperature, dry solids and C/N ratio on the growth of *E. fetida* and on vermicomposting of waste activated sludge was studied in a small-scale laboratory experiments. The maximum growth rate in 25°C, 15-20% dry solids and a C/N ratio of 15 were 19±1, 21±2 and 20±2 mg/worm/day, respectively. Moreover, changes in the physicochemical properties of the produced vermicasts were assessed. The highest VS reduction (18%) occurred in dry solids of 15% and in a C/N ratio of 25 the maximum VS reduction was 17%. TKN decreased with increase in dry solids by the end of vermicomposting process, while the highest organic to mineral P reduction occurred in the dry solids of 15%. The results for different levels of C/N ratio showed that TKN and organic to mineral P of the worm-worked waste activated sludge decreased with increase in C/N ratio. The pH of the produced vermicompost in different levels of dry solids and C/N ratio increased in all the experiments.

Key words: *E. fetida*, earthworm, municipal wastewater, vermicomposting

INTRODUCTION

Research into the potential use of earthworms to break down and manage sewage sludge began in the late 1970s[1] and the use of earthworms in the sludge management has been termed vermicomposting or vermistabilization[2,3]. Considerable work has been done on the use of earthworms in composting various organic materials and it has been established that epigeic forms of earthworms can enhance the composting process to a significant extent, with production of a better quality of final product[4]. Vermicomposting is a biooxidation and stabilization of organic material involving the joint action of earthworms and microorganisms. Although microbes are responsible for the biochemical degradation of organic matter, earthworms both physically and biochemically influence the process[5]. It was demonstrated quite early, at a laboratory scale, that aerobic sewage sludge can be ingested by the earthworm *Eisenia fetida* and that in the process the sludge is stabilized about three times as fast as non-ingested sludge and objectionable odors disappear quickly. Moreover, a market reduction occurs in populations of the pathogenic microorganisms *Salmonella enteriditis*, *E. coli* and other enterobacteriaceae[6]. Vermicomposting represents a technology that is environmentally sound, not to be energy, capital or equipment intensive and should not require extensive management.

The objective of this study was to evaluate the basic parameters including temperature, dry solids and carbon to nitrogen (C/N) ratio that may affect the performance of the vermicomposting process.

MATERIALS AND METHODS

This study was carried out at the Department of Environmental Health Engineering, Tehran University of Medical Sciences from March to July of 2003.

Waste activated sludge: The waste activated sludge (WAS) came from a sewage treatment plant that had virtually no industry influent and that had a well operated secondary treatment. The WAS was dewatered to dry solids of about 15%, without the use of chemicals, before being used in the experiments. Table 1 provides the waste activated sludge properties used in this study. The studies were conducted in plastic containers with a volume of 500 ml. Three replicates were used to evaluate specific parameters in each study.

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Table 1: The characteristics of the waste activated sludge used for vermicomposting

		Treatments					
		Dry solids (%)			C/N ratio		
Parameters	Temperature (°C)	10	15	20	15	25	35
DS*(%)	15.00±2.0	-	-	-	18±2	18±2	18±2
VS**(%) in DS	78.00±3.0	81	83	85	76	82	84
TOC***, % in DS	32.00±2.0	35	36	37	32	35	36
TKN+, % in DS	2.10±0.2	1.90	1.69	2.08	2.10	1.38	1.02
Organic P++, % in DS	1.40±0.1	1.80	1.62	1.39	1.98	1.52	1.39
Mineral P+++, % in DS	0.55	0.60	0.48	0.58	0.62	0.53	0.58
pH	6.40±0.1	5.80	5.90	5.80	6.2	5.70	5.80

*Dry solid; **Volatile solid; ***Total organic carbon; + Total kjeldahl nitrogen; ++Organic phosphorus; +++Mineral phosphorus

Parameters evaluated: Firstly, the effect of temperature on the growth of *Eisenia fetida* was evaluated to identify the optimum temperature for the earthworm in WAS. One hundred g wet weight of the WAS was placed in each container. Three non-clitellated earthworms weighing between 100 and 210 mg were added per container. The moisture content of the substrate throughout the experiment was kept at approximately 85% and the containers were placed in three incubators at 15, 20 and 25°C. Earthworm weight gain was measured weekly for four weeks.

In order to determine the optimal dry solids and its effect on vermicomposting process three experiments were conducted including 10, 15 and 20% dry solids. Three replicate containers each having three non-clitellated earthworms (*E. fetida*) were incubated at 25°C for 30 days. Two hundred g wet weight of the WAS was added to each container at the beginning of the study. Earthworm weight gain was measured weekly; the produced vermicasts were analyzed for the volatile solids (VS), pH, total kjeldahl nitrogen (TKN) and organic to mineral phosphorous (P) using the methods described in Standard Methods[7].

Three different C/N ratios of 15, 25 and 35 were studied in this experiment. Two hundred g wet weight of the WAS with dry solids of 15-20% was added to each container with three earthworms (*E. fetida*) that incubated at 25°C for 30 days. There were three replicates for each treatment. The moisture content was maintained in the containers through periodic sprinkling of distilled water. Earthworm weight gain was measured weekly. In the initial and final substrate of experiment the following parameters were determined according to Standard Methods[7]: VS, pH, TKN and organic to mineral P.

RESULTS

Effect of temperature: Earthworm growth over a 4 week study for *E. fetida* as a function of temperature was evaluated (Table 2). A one-way analysis of variance (ANOVA) was conducted on each of the responses studied. The mean growth rates at 15, 20 and 25°C were 15.8, 18.5 and 19 mg/day. The statistical analysis indicated no significant difference in the biomass change of earthworms between the dry solids of 15 and 20%, while there was a significant difference in dry solids of 10% in comparison with the other two dry solids ($p < 0.05$).

Effect of dry solids: The parameters of the feed WAS with desired dry solids were provided in Table 1. All the treatments indicated an increase in the biomass of earthworms (Table 2). The maximum weight of the earthworms in the WAS of 10, 15 and 20% dry solids were 720, 950 and 1100, respectively. The mean growth rates of 14.8, 22, 23 mg/worm/day were obtained in the substrates with 10, 15 and 20% dry solids, respectively.

Changes in the physicochemical properties of the produced vermicompost were determined after 30 days. The percent VS reduction (efficiency) for 10, 15 and 20% dry solids were 9.8, 18 and 11.7%, respectively (Table 3). A one-way analysis of variance (ANOVA) revealed a significant difference ($p < 0.05$) in percent VS reduction of various dry solids. The pH of the produced vermicompost was higher than the pH of the feed activated sludge (Table 3).

The highest (47%) and lowest (36%) TKN reduction ($p < 0.05$) were observed in dry solids of 20 and 10, respectively. Also, organic to mineral P reduced 70.6, 75 and 72% in dry solids of 10, 15 and 20%, respectively. For organic to mineral P, ANOVA showed no significant difference among the various dry solids investigated.

Effect of C/N ratio: Table 1 provides the characteristics of the WAS used to feed earthworm *E. fetida.* All the treatments indicated increase in the biomass of earthworms (Table 2). The maximum weight of the earthworms in the WAS of 15, 25 and 35 C/N ratios were 1200, 830 and 750, respectively. The mean growth rates of 22, 16 and 14 mg/worm/day were obtained in the C/N ratios of 15, 25 and 35, respectively. The rate of biomass production in C/N ratio of 15 was significantly higher ($p < 0.05$) than that in C/N ratios of 25 and 35.

The percentage changes in the physicochemical parameters of the worm-worked WAS were determined for the three levels of C/N ratios at the end of 4 week study.

Table 3 shows the percentage changes in VS of the vermicompost. The percent of VS reduction (efficiency)

Table 2: Growth rate of earthworm in different temperatures in the waste activated sludge

	Temperature (°C)			Dry solids (%)			C/N ratio		
Time	15	20	25	10	15	20	15	25	35
Week 1	15.5	15.0	15.5	14.0	21.6	21.0	20.0	15.0	12.0
Week 2	16.0	18.0	19.0	14.5	22.0	23.0	21.5	17.0	15.2
Week 3	15.8	19.5	20.0	15.8	23.0	24.5	23.3	16.2	15.0
Week 4	15.9	21.0	21.5	15.1	24.0	24.0	24.0	16.4	13.5

Table 3: Waste activated sludge characteristics at the beginning (B) and end (E) of the study

		Dry solids (%)			C/N ratio		
Parameters	Time	10	15	20	15	25	35
VS, % in	B	81.00	83.00	85.00	76.00	82.0	84.00
Dry solids	E	73.00	68.00	75.00	65.00	68.0	77.00
pH	B	5.80	5.90	5.80	6.20	5.70	5.80
	E	6.70	6.70	6.70	6.50	6.70	6.20
TKN&,% in	B	1.90	1.69	2.08	2.10	1.38	1.02
Dry solids	E	1.21	1.04	1.10	0.96	0.71	0.67
Org/M P&&	B	3.00	3.38	2.40	3.19	2.87	2.40
% in dry solids	E	0.88	0.84	0.67	0.24	0.67	0.68

& Total kjeldahl nitrogen
&& Organic to mineral phosphorus

for C/N ratios of 15, 25 and 35 was 14, 17 and 8%, respectively. Therefore, the optimum C/N ratio for VS reduction was 25. Percent reduction of VS for the three C/N ratios were significantly different ($p < 0.05$).

As with the results for dry solids, the pH of the product increased in all the experiments (Table 3).

The mean efficiency of TKN reduction for C/N ratios of 15, 25 and 35 were 54, 48 and 34%, respectively. There was a significant difference among the three C/N ratios for TKN reduction ($p < 0.05$). The highest reduction of organic to mineral P occurred in C/N ratio of 15 (92%) that was significantly higher ($p < 0.05$) than that in C/N ratios of 25 and 35.

DISCUSSION

The results indicated that there was not a significant difference between the growth rate of earthworm at 20 and 25°C, while earthworm growth rate at 15°C was significantly lower ($p<0.05$). In general, the optimum temperature for *E. fetida* was 25°C that is in good agreement with the earlier studies[8,9]. However, *E. fetida* has a broad temperature tolerance so that variations in actual vermicomposting systems within 15 to 25°C do not seem to be an important factor[3].

The VS reduction may be attributed to the mechanical action of earthworms increased the surface to volume ratio, thus augmenting the microbial activity in the substrates[10].

The result of pH reduction contradicts the observations from the earlier studies[11,12]. Haimi and Huhta[13] stated that the low pH might have been due to the production of CO_2 and organic acids by microbial activity during the vermicompost process; however, it seems that a pH drop by worm and microbial activity can proceed to some extent after which further processing of the acidic intermediates as well as assimilation of the resulting acidic species will have the pH shift reversing[14]. This result is in agreement with the earlier work of Datar *et al.*[15] whereby the pH increased with process time.

In general, the reduction of TKN content of the initial substrate was probably due to enhanced microbiological activity that increases nutrient mineralization rates; thus greater quantities of nitrogen will be available for plant use[16].

Other studies[17,18] also showed organic to mineral P decrease during vermicomposting of the various organic matter. The rise in the level of organic to mineral P during vermicomposting is probably due to mineralization of organic P by the combined action of faecal phosphatases (both acid and alkaline phosphatase) of earthworms and microbial activity of the casts[19].

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