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Effect of C/N ratio on Vermicomposting of Vegetable Waste

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ABSTRACT

A study (42 days duration) was conducted to evaluate the best C/N (carbon: nitrogen) ratio for vermicomposting of vegetable waste blended with cow dung and saw dust by analysis of various parameters i.e. pH, total organic carbon (TOC), electrical conductivity (EC), total nitrogen (TN), chemical oxygen demand (COD) and metals, for this study an exotic earthworm species- *E. fetida* was used. Four different reactors R1, R2, R3 and R4 with C/N ratios of 20, 30, 40 and 16.4, respectively were tested. After 42 days of vermicomposting, it was found that C/N ratio significantly affected the growth and reproduction of *E. fetida*. The decrease in COD varied significantly ($p<0.05$) in all the three reactors R1, R2 and R3 with highest percentage decrease in R2 which was found to be 78.02% while in R1 and R3 it was 66.64% and 75.78% respectively. The increase in TN content varied significantly in all the reactors on all the days ($p<0.05$) with maximum percentage increase of 73.58% in R2 as compared to 42.51% and 61.62% in R1 and R3, respectively.

Keywords: C/N, cow dung, *E. fetida,* vegetable waste, sawdust, vermicomposting
Abbreviations: COD, chemical oxygen demand; **EC**, electrical conductivity; **TOC**, total organic carbon; **TN**, total nitrogen

INTRODUCTION

Modern society, with its high population densities, heavy industrialization and intensive methods of agriculture produces ever increasing quantities of solid wastes. It has been estimated that in India, as a whole, 25 million tones of urban solid waste of diverse composition is generated per year (Aalok *et al*. 2008). The per capita waste generated in India is about 0.4 kg/day with approximately 50-60% being compostable matter (Aalok *et al*. 2008). One of the major sources of urban solid waste in India is household kitchen waste; domestic waste is mostly of organic nature and contributes 70 to 80% of urban solid wastes (Kale 1998). Each household of four family members generates 0.5-0.75 kg kitchen wastes per day (Kale 1998). Under the present condition of environmental degradation vermicomposting offers recovery of valuable resources like manure from organic waste. Domínguez (2004) described the vermicomposting, saying that "earthworms act as mechanical blenders, and by comminuting the organic matter, they modify its biological, physical and chemical status, gradually reducing its C/N ratio, increasing the surface area exposed to microorganisms, and making it much more favorable for microbial activity and further decomposition". Compost scientists have determined that the fastest way to produce fertile, sweet-smelling compost is to maintain a C/N ratio somewhere around 25 to 30 parts carbon to 1 part nitrogen, or 25-30:1. If the C/N ratio is too high (excess carbon), decomposition slows down. If the C/N ratio is too low (excess nitrogen) you will end up with a stinky pile.

Vermicomposting has been reported to be a viable, cost-effective and rapid technique for the efficient management of organic solid wastes (Logsdon 1994). Vermicomposting, utilizing earthworms, is an eco-biotechnological process that transforms energy-rich and complex organic substances into a stabilized humus-like product (Benitez *et al*. 2000). Vermicomposting is an important aspect, as it converts waste to wealth by using cheap eco-friendly option with activity of earthworm (Mall *et al*. 2005).

The aim of this experiment was to carry out vermicomposting of vegetable waste blended with cow dung and saw dust at different C/N ratios, to find out the best C/N ratio for vermicomposting, and to explore the potential of an exotic earthworm species, *E. fetida*, for utilizing vegetable waste while assessing the adaptability of these worms.

Saw dust was used as a bulking agent in the study. Suthar (2009) reported that bulking agents plays important role during vermicomposting of organic wastes. The type and proportion of bulking material in vermireactors not only influences the mineralization rate but at the same time also alters the earthworm biomass production rate. Earlier studies have revealed that mixing of bulking material in some noxious wastes minimizes the concentration of toxic substances in vermireactors and consequently speeds the decomposition process. The importance of bulking material in vermicomposting of waste is as follows: (1) it makes the waste more acceptable for earthworms (Domínguez 2004), (2) lowers the concentration of some unfavorable chemicals (Suthar 2007b), (3) sets the pH within the acceptable limit for earthworms (Suthar 2006), (4) may enhance the nutritive value of waste and thereby accelerate the decomposition through enzymes production by earthworm itself and associated micro flora (Flegel and Schreder 2000), (5) enhances the quality of ready product, i.e., vermicompost by adding some important nutrients (Suthar 2008a), and (6) changes the microclimatic conditions of the decomposing waste by promoting microbial colonization in feedstock, although microbes are important part of earthworm diet (Suthar 2008b).

MATERIALS AND METHODS

Collection of earthworms

E. fetida, being the most commercially used worm for vermicomposting (Khwairakpam and Bhargava 2009), was used for the study. *E. fetida* were obtained from a Non-Government Organization (NGO), Morraka foundation working in Jaipur, India. They were then cultured in the laboratory and randomly selected for experimentation.

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Table 1 The composition of feedstock in various reactors.

Reactor No.	C/N ratio	Vegetable waste (g)	Cow dung (g)	Saw dust (g)
R1	20	600	391	9
R2	30	600	387	13
R3	40	600	382	18
R4	16.4	1000	0	0

Vegetable waste

Vegetable waste, obtained from Malviya National Institute of Technology (MNIT), Jaipur, was kept in the shade for 1-2 weeks for partial decomposition of waste, before using for vermicomposting. The partially degraded vegetable waste was then blended with cow dung and saw dust in different proportions. This was done so as to vary the C/N ratios in all the reactors. The obtained mixture was used as raw material for vermicomposting. The composition of feedstock in various reactors is given in **Table 1**.

Experimental design

The experiments were conducted in triplicate in four sets in plastic containers of 20 L capacity in the open without any temperature control. For aeration and drainage, 0.5 cm diameter holes were drilled: 20 holes along the circumference and 20 holes at the bottom. Bedding (10-cm thick) made up of old vermicompost was kept in all four containers. Then one kg of composting mixture was added to each container. The quantity of mixture was decided based on the findings that earthworms can consume half of their body weight of material per day under favorable conditions (Haimi and Huhta 1986). The initial C/N ratio of all four containers was 16.4, 20, 30 and 40, respectively. In the reactors 50 g earthworms of approximately the same size were introduced. Moisture level was maintained by visual inspection at about 50–60% throughout the study period by periodic sprinkling of tap (potable) water. The experimental reactors were kept under shade and covered with the gunny bags to avoid direct sunlight and prevent moisture loss.

Compost analysis

According to Garg *et al*. (2006) about 110 g of homogenized wet samples (free from earthworms, hatchlings and cocoons) were taken out at zero day and on the 7th, 14th, 21st, 28th, 35th and 42nd day of composting period. Day zero refers to the sample taken out before earthworm inoculation. Determination of pH was done by a digital pH meter (ELICO-L11 62), electrical conductivity by a conductivity meter (ELICO-180) and ash content by a muffle furnace (Scientific New Delhi-SMF36), total organic carbon was estimated by a Photochem Organic Carbon Analyzer (Sybron) and total Kjeldhal N was estimated by an Elemental Analyzer (USDA and USCC 2002). Chemical oxygen demand (COD) was measured using open reflux COD. In addition, earthworm growth-related parameters like earthworm biomass and total mortality were measured at the end of the vermicomposting process i.e. on 42nd day of vermicomposting in which total food waste was converted into manure.

Statistical analysis

Statistical analysis was carried out with Statdirect software. One-way analysis of variance (ANOVA) was done to analyze the significant differences between treatment means during vermicomposting using Tukey's Honest Significant Difference (HSD) at $P < 0.05$. All results reported are the means of three replicates.

RESULTS AND DISCUSSION

Worm population mass

In R4 only vegetable waste was used which was highly putrescible or contained excessive amounts of protein or other readily degradable organic compounds. In this reactor the earthworms became inactive within 2 days and died within 4 days. Fresh vegetable waste has a high amount of organic matter and high moisture content that promotes the formation of anaerobic conditions. In anaerobic conditions alcohol, ammonia, acetic acid and methane gas are produced which might temporally increase the pH and could be lethal to earthworms (Frederickson and Knight 1988). However, in the other 3 reactors worms survived, grew and multiplied. The percentage increase of worms was highest in R3, 0.12%; this may be possibly due to the bedding layer facilitating the maintenance of favorable environmental conditions inside the reactor. High proportion of saw dust as compared to other 3 reactors may also be the reason for the highest increase of worms in R3.

pH

The end products from the three reactors showed a similar pattern of change in pH. The substrate pH attained an increasing trend for all the reactors (**Table 2**). For R2, the pH first increased and then started to decrease after the 4th week. Increase in pH might be attributed due to decomposition of organic matter which further leads to formation of ammonium ion and humic acids (Komilis and Ham 2006). Datar *et al*. (1997) and Nogales *et al*. (1998) also reported an increase in pH with time during the vermicomposting process. Singh *et al*. (2005) reported that the initial increase in substrate pH can be attributed to the fact that initially microbes participate in the degradation representing aerobic metabolism. pH showed a significant variation on 0th, 7th, 14th, 21st, 28th, 35th sampling day but later on showed a non-significant variation on 42nd sampling day.

Electrical conductivity

Gradual increase in EC was recorded in all the three reactors R1, R2 and R3 with increase in decomposition time (**Table 2**). The increase in EC may be due to loss of weight of organic matter and release of different mineral salts in available forms (such as phosphate, ammonium, and potassium) as reported by other researchers (Garg *et al*. 2006). Significant variation was observed on all the sampling days for EC except for 0 day as per ANOVA.

Table 2 Variation in pH, EC and ash content during vermicomposting of vegetable waste.

	0 days	7 days	14 days	21 days	28 days	35 days	42 days
pH							
R1	6.80 ± 0.03a	7.00 ± 0.03a	7.00 ± 0.03a	7.30 ± 0.03a	7.75 ± 0.05a	8.25 ± 0.05a	8.09 ± 0.15a
R2	7.00 ± 0.03b	7.00 ± 0.03b	7.20 ± 0.03b	7.30 ± 0.03a	7.96 ± 0.05b	6.96 ± 0.05b	8.18 ± 0.15a
R3	6.90 ± 0.03c	7.10 ± 0.03c	6.80 ± 0.03c	7.10 ± 0.03b	7.80 ± 0.05a	8.02 ± 0.05c	8.18 ± 0.15a
EC (ms/cm)							
R1	0.45 ± 0.05 a	0.53 ± 0.05 a	0.87 ± 0.05 a	1.26 ± 0.05 a	1.56 ± 0.05 a	1.90 ± 0.05 a	2.31 ± 0.05 a
R2	0.40 ± 0.05 a	0.50 ± 0.05 ab	0.68 ± 0.05 bc	0.98 ± 0.05 bc	1.28 ± 0.05 bc	1.69 ± 0.05 bc	2.12 ± 0.05 bc
R3	0.49 ± 0.05 a	0.65 ± 0.05 ac	0.90 ± 0.05 ad	1.35 ± 0.05 ad	1.70 ± 0.05 d	2.12 ± 0.05 d	2.36 ± 0.05 ad
Ash content (%)							
R1	15.66 ± 1.20a	16.76 ± 1.20a	17.90 ± 1.20a	18.62 ± 1.20a	19.34 ± 1.20a	20.48 ± 1.20a	21.60 ± 1.20a
R2	16.20 ± 1.20a	18.85 ± 1.20a	19.14 ± 1.20a	19.83 ± 1.20a	20.78 ± 1.20a	20.98 ± 1.20a	22.70 ± 1.20a
R3	17.56 ± 1.20a	22.00 ± 1.20b	23.96 ± 1.20b	24.77 ± 1.20b	25.50 ± 1.20b	26.39 ± 1.20b	26.60 ± 1.20b

All data represent average of triplicates. Values followed by the same letter within each column are not significantly different.

Table 3 Variation in TOC, Nitrogen and COD during vermicomposting of vegetable waste.

	0 days	7 days	14 days	21 days	28 days	35 days	42 days
TOC (%)							
R1	41.00 ± 0.57a	38.52 ± 0.57a	37.50 ± 0.57a	36.23 ± 1.15a	35.24 ± 1.15a	33.44 ± 0.33a	33.35 ± 0.32a
R2	43.00 ± 0.57b	41.20 ± 0.57b	40.50 ± 0.57b	39.60 ± 1.15a	38.01 ± 1.15b	36.05 ± 0.33b	36.00 ± 0.32a
R3	45.00 ± 0.57c	43.50 ± 0.57c	42.20 ± 0.57c	41.50 ± 1.15b	39.70 ± 1.15a	37.90 ± 0.33c	37.35 ± 0.32a
Total nitrogen (%)							
R1	2.01 ± 0.05a	2.44 ± 0.05a	2.48 ± 0.05a	2.65 ± 0.05a	2.75 ± 0.05a	2.90 ± 0.05a	3.00 ± 0.05a
R2	1.35 ± 0.05b	1.76 ± 0.05b	2.01 ± 0.05b	2.30 ± 0.05b	2.45 ± 0.05b	2.49 ± 0.05b	2.65 ± 0.05b
R3	1.12 ± 0.05c	1.30 ± 0.05c	1.52 ± 0.05c	1.69 ± 0.05c	1.85 ± 0.05c	1.89 ± 0.05c	2.00 ± 0.05c
COD (mg/l)							
R1	901.20 ± 100a	800.20 ± 90a	672.75 ± 75a	572.75 ± 65a	437.69 ± 40a	322.63 ± 35a	300.64 ± 30a
R2	925.30 ± 100a	813.81 ± 90a	728.81 ± 75a	568.81 ± 65a	469.49 ± 40a	388.61 ± 35a	203.39 ± 30bc
R3	963.02 ± 100a	829.88 ± 90a	714.04 ± 75a	634.09 ± 65a	474.86 ± 40a	323.20 ± 35a	233.25 ± 30c

All data represent average of triplicates. Values followed by the same letter within each column are not significantly different.

Table 4 Variation in C/N ratio during vermicomposting of vegetable waste.

Reactors	0 days	7 days	14 days	21 days	28 days	35 days	42 days
R1	20.39 ± 0.43a	15.59 ± 0.43a	15.12 ± 0.60a	13.67 ± 0.60a	12.81 ± 0.60a	11.53 ± 0.26a	11.12 ± 0.26a
R2	31.85 ± 0.43b	23.41 ± 0.43b	20.15 ± 0.60b	17.22 ± 0.60b	15.51 ± 0.60b	14.48 ± 0.26b	13.58 ± 0.26b
R3	40.18 ± 0.43c	33.46 ± 0.43c	27.76 ± 0.60c	24.56 ± 0.60c	21.46 ± 0.60c	20.05 ± 0.26c	18.68 ± 0.26c

All data represent average of triplicates. Values followed by the same letter within each column are not significantly different.

Ash content

Ash content was observed to be increasing with the increase in vermicomposting time in all the reactors (**Table 2**). R3 showed fastest rate of volatilization and simultaneous increase in ash content from 17.56 to 26.60% i.e., a 44.80% increase. Similar observations have also been reported by Atiyeh *et al*. (2000), Kavian *et al*. (1991) and Singh *et al*. (2005). R1 and R2 showed a relatively slower increase in the ash content as compared to R3. The increase in the ash content shows that waste was consumed by earthworms at a faster rate and that the microbial assimilation also performed the decomposition process at a good pace. Ash content varied significantly ($P < 0.05$) on all the sampling days except for 0 day sample as per ANOVA analysis of variance.

Total organic carbon (TOC)

A large fraction of TOC was lost as carbon dioxide in the process of respiration. The percentage decrease observed in R1, R2 and R3 was 20.2, 17.43 and 18.3%, respectively (**Table 3**). TOC showed a significant variation on 0th, 7th, 14th, 21st, 28th, 35th day sample but no significance was shown on 42nd day. The reduction in organic carbon could be due to the respiratory activity of earthworms and microorganisms (Curry *et al*. 1995; Edwards and Bohlen 1996; Ananthakrishnasamy *et al*. 2009). The observed results are supported by those of other researchers (Kaviraj and Sharma 2003) who have reported 20–45% reduction of TOC as carbon dioxide during vermicomposting of municipal or industrial wastes.

Chemical oxygen demand (COD)

The percentage of readily biodegradable organic matter (BOM) is an important aspect of compost quality. There is a decreasing trend of COD with the composting time in all the three reactors. The percentage decrease was highest in R2 and was found to be 78.02% while in R1 and R3 it was 66.64 and 75.78%, respectively (**Table 3**). As long as the BOM content as COD was decreased, this resulted in decreasing emission of carbon dioxide, suggesting that compost has undergone stabilization. COD showed a non-significant variation on 0th, 7th, 14th, 21st, 28th, 35th sampling day but later on showed a significant variation on the 42nd day sample.

Total nitrogen content

There was increase in percentage of total nitrogen of the vermicompost for all the 3 reactors with maximum increase of 73.58% in R2 as compared to 42.51 and 61.62% in R1 and R3, respectively (**Table 3**). This shows that worms consumed large amount of organic matter that contains considerable quantities of nitrogen, and much of this is returned to the soil in their excretions (Edward *et al*. 1976). According to Viel *et al*. (1987) loss in organic carbon might be responsible for nitrogen enhancement. Earthworms also have a great impact on nitrogen transformations in manure, by enhancing nitrogen mineralization, so that mineral nitrogen may be retained in the nitrate form (Atiyeh *et al*. 2000). Garg *et al*. (2006), Kaushik and Garg (2004) and Elvira *et al*. (1996) reported 1.8-2.5 times increase in nitrogen content during the mineralization of waste. Higher significance was observed in the values of total nitrogen for all the reactors ($P < 0.05$).

C/N ratio

The end product i.e. vermicompost obtained in end of this experimental study had lower C/N ratio as compared to the initial value. The C/N ratio reflects the spectra of changing carbon and total nitrogen concentration of the substrate material during vermicomposting process. C/N ratio of the vermicompost decreased from a initial value of 20.39% to a final value of 11.12% at the end of 42 days in R1, 31.85 to 13.58% in R2 and 40.18 to 18.68% in R3.The rate of decrease of C/N ratio was fastest in R2 i.e. 77.72% as compared to 56.29 and 71.34% in R1 and R3, respectively (**Table 4**). The decrease in C/N ratio over time might also be attributed to increase in the earthworm population which led to rapid decrease in organic carbon due to enhanced oxidation of the organic matter (Ndegwa and Thompson 2000). The release of part of the carbon as carbon dioxide (CO_2) in the process of respiration, production of mucus and N excrements, increases levels of N and lowers the C/N ratios (Senapati *et al*. 1980). Significant change was observed in the values of C/N ratio for all the reactors ($P < 0.05$) on all the sampling days.

CONCLUSION

The efficiency of vermicomposting process using *E. fetida* on the basis of nutrient content (N) of the compost was found maximum for R2 with C/N ratio 30 but for earthworm growth R3 with C/N ratio 40 was found most suitable. Therefore it can be concluded that C/N ratio 30 is best ratio for vermicomposting on the basis of quality of compost obtained finally. It was also found that earthworms did not survive in R4 which did not have any bedding material and only had vegetable waste which shows that bedding is essential while using vegetable waste alone as a feedstock and bedding should retain moisture, remain loose in the pile, and not contain excessive amount of high protein.

Experimental data provides a sound basis that vermicomposting using *E. fetida is a* novel technique of converting decomposable organic wastes into valuable vermicompost through earthworm activity, especially at C/N ratio 30/1, which is a faster and good process than the conventional methods of compost preparation and temperature, type of feedstock influence the activity, metabolisms, growth and reproduction of *E. fetida*. Analysis of vermicompost obtained clearly indicates its utility as soil conditioner and good source for plant nutrients in agriculture. In view of ecological aspects, potential of Indigenous species in agriculture needs to be explored.

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