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Research Article

EFFECTIVENESS OF INDIGENOUS EARTHWORM SPECIES ON MAJOR NUTRIENT CHANGES DURING BIOCONVERSION OF COFFEE PULP AMENDED WITH PRESSMUD

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ABSTRACT

Application of fresh organic wastes or non-stabilized compost to soil may leads to immobilization of plant nutrients and cause phytotoxicity. Annually, large amount of coffee by-products are generated throughout coffee processing industry. The environmental problems associated with raw coffee pulp (CP), such as release of polyphenols and tannins could be mitigated by stabilizing its nutrient and organic matter contents by vermicomposting before application to agricultural soils. The objectives of this study was to evaluate the changes in nutrient content of CP amended with sugarcane press mud (SPM) using earthworms and vermicomposting during over a period of 75 days in order to produce stabilized organic fertilizer. Results revealed that nutrient contents during vermicomposting showed a significant variation in all the treatments ($p<0.05$) for all the sampling days for both species than natural composing. Among the different treatments PT4, PT5 and PT6 treatments for *P.ceylanensis* and LT10, LT11 and LT12 for *L. mauritii* treatments showed significantly ($p<0.05$) higher level of nutrients than other treatments and natural composting treatments.

Keywords: Vermicomposting, Coffee pulp, Press mud, Nutrients, Naive earthworms.

INTRODUCTION

Biological management of organic solid waste have been widely recognized as the most efficient, sustainable and environmentally friendly methods for converting into hygienically safe and valuable products (Garg *et al.*, 2005). In terms of its economical costs and simple process, composting was used widely, especially in developing countries. Composting and vermicomposting technologies are emerging quickly valuable tools in pollution prevention and control. Moreover, with regard to the concerns on global warming, composting and vermicomposting is playing a major role. The optimization of the biological methods for decentralized systems still needs to be investigated more (Gupta and Garg, 2008). Thus, what is need for the existing condition is an innovative method of recycling of organic wastes to produce organic manure at a minimum time in a minimum space and at minimum cost. Hence, appropriate method of disposal or recycling of wastes would be most beneficial from environmental, agricultural and economical point of view, to derive beneficial product from wastes, several techniques are available, and all the techniques are mainly based on the concept of recycle, reuse and recovery of resources.

Coffee is one of the worldwide agricultural products and is the second chief product traded in the world subsequently to oil. Annually, large amount of coffee by-products are generated throughout coffee processing. In recent past, emphasis on use of organic manures has assumed increased significance as it finds a place in organic farming and as well in integrated nutrient system. Coffee processing units those are situated in coffee growing areas pretense threat to the environment because of unsafe discarding of coffee pulp, husk and effluents leading to pollution of water and land around the processing units (Pushpa and Manonmani, 2008). Large potentialities exist for recycling of both pulp and husk of coffee that can be composted and used as manure for several crops. Coffee pulp could be useful because of its high content of carbohydrates and proteins. However, the presence of caffeine, tannins and polyphenols limits its utilization. However, composting and/or vermicomposting of these

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wastes over attractive recycling alternatives (Pandey *et al.*, 2000).

In India, sugar industry with 400 sugar mills rank as the second major agro industry in the country. The cane-sugar manufacturing has a number of co-products of immense potential worth. The co-products include pressmud and molasses. Out of which pressmud is produced during clarification of sugarcane juice. About 3.5 – 4.3% of sugarcane packed down end up as pressmud i.e. 36 - 40 kg of pressmud is obtained after one ton of cane crushing. However, pressmud is directly applied to soil as manure; the buff present might worsen the physical properties such as permeability, aeration, soil structure and composition etc. and with the passage of time the deterioration might get worsen (Mnivannan, 2005). In this research, the main focus is to use one of the sugar industries by products by - product i.e. pressmud (excellent organic amendments for vermicomposting) which is converted in to vermicompost mixed with coffee pulp using local earthworms. Vermiomposting is successful method for changing organic solid waste in to manure that is well-off of nutrients. Because vermicompost is biologically well-matched than chemical fertilizers for soils and plants, vermicomposting has become a preferred choice for treating organic solid waste. Keeping in view of the above, the aims of this study were to assess the ability of these earthworm species *P. ceylanencis* and *L. mauritii* used as degrader to efficiently decompose coffee pulp with bulking agent pressmud into stabilized product by monitoring the nuriens.

MATERIALS AND METHODS

Selection of local earthworms

Indigenous, efficient epigeic species *Perionyx ceylanensis* (Mich.) were compared with another local earthworm species *Lampito mauritii* (Kinberg) for their survival and degradation efficiency of selected waste materials. Indigenous earthworm's *P. ceylanensis* and *L. mauritii* were obtained from the stock culture which was cultivated in cow dung in the laboratory, Department of Zoology, Annamalai University, India. The worms were stocked in cement tank and one month old cow dung was used as substrate to maintain the both earthworms.

Collection of coffee pulp (CP) and sugar industry press mud (SPM)

The coffee pulp (CP) waste (fifteen days old) of *Coffea arabica* was collected from the JSP plantation coffee seed processing industry at Yercaud in Salem district, Tamilnadu, India. Sugar industry by product press mud (SPM), also called filter mud was procured from E.I.D. Parry's Sugar Mill located at Nellikuppam, Cuddalore District, Tamil Nadu, India. Fresh SPM was kept under shade for 2-3 weeks to remove the foul smell before using for the experimental process. The initial physico-chemical characteristics of CP and SPM are given in Table 2.

Experimental design

In the present study, different proportions of Coffee pulp (CP) with bulking material Sugar industry press mud (SPM) mixtures were prepared (Table 1). Coffee pulp (CP) and Sugar industry press mud (SPM) was weighed (dry weight) in the above said description and mixed well with 65-75% moisture content. The waste mixtures, CP and SPM were transferred to separate plastic troughs with 40cm diameter x 60cm depth, respectively. After transferred in the plastic troughs all the mixture compositions of CP and SPM were allowed for seven days of initial natural decomposition. PT1, PT2, PT3, PT4, PT5 and PT6 treatments were composed of different proportions of CP and SPM with *P. ceylanensis*. LT6, LT7, LT8, LT9, LT10 and LT12 treatments were composed of different proportions of CP and SPM with *L. mauritii*. Treatments of CT13, CT14, CT15, CT16, CT17 and CT18 were composed of different proportions of CP and SPM without earthworms (Table 1). All the experimental treatments were kept in six replicate for each treatment in a completely randomized block design. Matured earthworms were used in this experiment, with an average weight of 109 to 112mg of *P. ceylanensis*$^{-1}$ and 135 – 141mg of *L. mauritii*$^{-1}$ with a developed clitellum. The troughs were filled with 5kg substrate per troughs in above combinations. The troughs were kept under shade and irrigated with equal quantity of water to ensure that the substrate moisture content was maintained at approximately 65-75%. After the completion of pre-inoculation period of 7days, the clitellated *P. ceylanensis and L. mauritii* were weighed and inoculated in to respective each treatment (Manivannan, 2005).

Growth and reproduction study and Nutrient analysis

On the basis of collected data of biomass and cocoon and hatchling numbers, other growth parameters of both earthworms, i.e. mean initial biomass (mg), maximum biomass achieved (earthworm^{-1} mg), biomass gain (earthworm^{-1} mg), growth rate (earthworm^{-1} day^{-1} mg) and reproduction rate cocoon and hatchlings (total number) were produced with the help of recorded data, for different studied treatments of both worms. Samples were collected periodically from each treatment for nutrient analysis. Total organic carbon (TOC) content in the sample was determined by chromic oxidation method (Walkely and Black, 1934). Furthermore total Kjeldhal nitrogen (TKN) was measured by micro Kjeldhal method (Tiquia, 2005). Total phosphorus (TP) was estimated by vanadomolybdo phosphoric acid yellow colour method using a colorimeter (Model 115, Systronics, India) (Jackson, 1973).While Total potassium (TK) was detected by the method of Jackson (1973) using flame photometer (Model 128, Systronics, India). C: N was considered from the measured value of C and N. Exchangeable elements (Na, Ca, and Mg) were determined after extracting the sample using ammonium acetate extract ionmethod. Results are the means of the three replicates. Two way analysis of variance (ANOVA) was performed by using the SPSS 10.5 software. The objectives of statistical analysis to determine any significant differences among the parameters analyzed in different treatments during the composting process. Results are the means of the three replicates. Two way analysis of variance (ANOVA) was performed by using the SPSS 10.5 software. The objectives of statistical analysis to determine any significant differences among the parameters analyzed in different treatments during the composting process.

RESULTS

The organic wastes, CP and SPM used in this study were analyzed prior to composting and vermicomposting and their initial properties are given in Table 2. Total organic carbon (TOC) decreased in all treatments of both worms after vermicomposting process, significantly in those treatments which contained up to 60% CP with SPM. At the end of experiment, the final TOC of vermicompost was lesser than initial organic matter content. In the present study, TOC content was lesser in vermicompost of all the treatments especially, PT4, PT5 and PT6 in *P. ceylanensis* and LT10, LT11 and LT12 in *L. mauritii* showed significantly ($p < 0.05$) reduced TOC contents by the end of vermicomposting than other treatments of both worms and natural composting (Table 3). The TKN (%) content of the vermicompost varied from 1.71±0.11 to 2.33±0.04 for *P. ceylanensis* and 1.73±0.09 to 2.27± 0.06 for *L. mauritii* (Table 4). The increase in TKN content during vermicomposting was in the range of 27.5 to 132.4% for *P. ceylanensis* and 25.6 to 121.5% for *L. mauritii*. At the end of vermicomposting total phosphorous (TP) content of the vermicompost produced from different treatments of *P. ceylanensis* and *L. mauritii* was significantly increased as compared to the initial substrate and natural compost (Table 5). In this study, the TK (%) content for initial substrate material was in the range from 0.81±0.02 to 1.35±0.03. However, the TK content of the vermicompost varied from 1.71±0.09 to 2.33±0.11 for *P. ceylanensis* and 1.71 ±0.06 to 2.33 ±0.08 for *L. mauritii* (Table 6).

The C:N ratio of vermicompost obtained from different treatments of both species of worms were decreased significantly as compared to the initial substrate material after vermicomposting (Table 7). The level of micro nutrients Ca, Mg and Na of vermicompost produced by *P. ceylanensis* and *L. mauritii* showed significant difference in all the treatments (PT1 to LT12). However, PT4, PT5 and PT6 treatments for *P. ceylanensis* and LT10, LT11 and LT12 for *L. mauritii* treatments showed significantly ($p<0.05$) higher level of micro nutrients than other treatments and natural composting treatments (Table 8, 9 and 10). In general, in the present analysis, the TOC and C: N ratio were significantly ($p<0.05$) reduced in vermicomposting treatments. On the other hand macro nutrients (TKN, TP and TK) and micro nutrients (Ca, Mg and Na) were found to have increased significantly ($p<0.05$) in all the treatments than Natural composting. Among the different treatments, PT4, PT5 and PT6 treatments for *P. ceylanensis* and LT10, LT11 and LT12 for *L. mauritii* showed significantly ($p<0.05$) higher level of macro and micro nutrients than other treatments and natural composting. Of the two indigenous species of worms, the vermicompost of *P.ceylanensis* exhibits more mineral nutrients than *L. mauritii*.

Table 1. Description of different treatments with coffee pulp and sugar industry press mud used for experimentations.

Treatments	Coffee Pulp (CP)	Sugar Industry Pressmud (SPM)
	Perionyx ceylanensis	
PT1	CP 100%	SPM 0%
PT2	CP 0%	SPM 100%
PT3	CP 80%	SPM 20%
PT4	CP 60%	SPM 40%
PT5	CP 40%	SPM 60%
PT6	CP 20%	SPM 80%
	Lampito mauritii	
LT7	CP 100%	SPM 0%
LT8	CP 0%	SPM 100%
LT9	CP 80%	SPM 20%
LT10	CP 60%	SPM 40%
LT11	CP 40%	SPM 60%
LT12	CP 20%	SPM 80%
	Composting (without worms)	
CT13	CP 100%	SPM 0%
CT14	CP 0%	SPM 100%
CT15	CP 80%	SPM 20%
CT16	CP 60%	SPM 40%
CT17	CP 40%	SPM 60%
CT18	CP 20%	SPM 80%

CP- Coffee Pulp; SPM- Sugar industry Press mud; PT – Treatments with *Perionyx ceylanensis*; LT - Treatments with *Lampito mauritii*; CT - Composting without earthworms.

Table 2. Initial physico-chemical characterizations of the CP and SPM.

Parameters	TOC	TKN	TP	TK	Na	Ca	Mg	C:N ratio
	(%)				($mg\ kg^{-1}$)			
CP	41.14±0.51	0.98±0.07	0.32±0.04	0.91±0.11	219±0.42	375±0.52	178±0.19	41.8±0.5
SPM	54.4±0.24	1.12±0.05	0.85±0.07	0.98±0.09	198±0.21	295±0.18	190±0.21	48.2±0.8

All values are mean and standard deviation of six replicates.

Table 3. Decline TOC during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	TOC (%) Days 0	25	50	75
Perionyx ceylanensis				
PT1	39.5 ± 0.23[a]	40.8 ± 0.29[a]	31.6 ± 0.18[b]	21.9 ± 0.29[ab]
PT2	47.2 ± 0.32[b]	48.5 ± 0.30[b]	28.2 ± 0.29[b]	20.6 ± 0.35[ab]
PT3	43.5 ± 0.19[ab]	45.6 ± 0.19[ab]	27.6 ± 0.35[ab]	19.5 ± 0.19[ab]
PT4	39.7 ± 0.21[ab]	40.5 ± 0.21[ab]	25.5 ± 0.17[ab]	18.7 ± 0.34[a]
PT5	33.8 ± 0.35[a]	34.8 ± 0.35[a]	23.4 ± 0.41[a]	15.6 ± 0.25[a]
PT6	34.8 ± 0.74[a]	39.9 ± 0.74[a]	26.5 ± 0.49[a]	18.5 ± 0.16[a]
Lampito mauritii				
LT7	39.5 ± 0.23[a]	40.9 ± 0.35[a]	33.5 ± 0.25[c]	22.3 ± 0.55[ab]
LT8	47.2 ± 0.32[b]	47.6 ± 0.19[b]	30.4± 0.20[b]	20.9 ± 0.30[ab]
LT9	43.5 ± 0.19[ab]	46.5 ± 0.15[ab]	29.5 ± 0.31[ab]	20.8 ± 0.27[ab]
LT10	39.7 ± 0.21[ab]	39.8 ± 0.42[ab]	27.6 ± 0.27[a]	19.5 ± 0.19[a]
LT11	33.8 ± 0.35[a]	35.5 ± 0.29[a]	25.4 ± 0.30[a]	16.7 ± 0.41[a]
LT12	34.8 ± 0.74[a]	36.4 ± 0.40[a]	28.5 ± 0.49[a]	19.3 ± 0.37[a]
Composting (without worms)				
CT13	39.5 ± 0.18[a]	41.2 ± 0.22[a]	40.6 ± 0.18[a]	39.5 ± 0.50[ab]
CT14	47.2 ± 0.29[b]	49.6 ± 0.17[b]	38.7 ± 0.25	37.7 ± 0.29[ab]
CT15	43.5 ± 0.20[ab]	48.5 ± 0.35[ab]	38.5 ± 0.35[ab]	37.6 ± 0.45[ab]
CT16	39.7 ± 0.35[ab]	42.1 ± 0.29[ab]	37.4 ± 0.40[ab]	36.5 ± 0.27[a]
CT17	33.8 ± 0.19[a]	41.2 ± 0.49[a]	37.2 ± 0.51[a]	35.1 ± 0.31[a]
CT18	34.8 ± 0.25[a]	42.3 ± 0.51[a]	37.5 ± 0.11[a]	35.7 ± 0.19[a]

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 4. TKN (%) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	TKN (%) Days 0	25	50	75
Perionyx ceylanensis				
PT1	1.41± 0.08[a]	1.43± 0.09[a]	1.69± 0.02[a]	1.71 ± 0.11[a]
PT2	1.48 ± 0.05[b]	1.49 ± 0.06[a]	1.75 ± 0.04[a]	2.24 ± 0.08[b]
PT3	1.42± 0.07[a]	1.44± 0.04[a]	1.72 ± 0.05[a]	1.85 ± 0.09[a]
PT4	1.45± 0.07[ab]	1.49± 0.05[a]	2.18 ± 0.03[b]	2.25 ± 0.07[b]
PT5	1.45 ± 0.04[ab]	1.50 ± 0.06[ab]	2.21 ± 0.05[b]	2.31 ± 0.05[bc]
PT6	1.47 ± 0.03[ab]	1.51 ± 0.05[ab]	2.23 ± 0.04[b]	2.33 ± 0.04[bc]
Lampito mauritii				
LT7	1.41± 0.08[a]	1.40± 0.05[a]	1.60± 0.05[a]	1.73 ± 0.09[a]
LT8	1.48 ± 0.05[b]	1.48 ± 0.09[a]	1.92 ± 0.07[a]	2.20 ± 0.05[b]
LT9	1.42± 0.07[a]	1.43± 0.04[a]	1.69 ± 0.05[a]	1.90 ± 0.08[a]
LT10	1.45± 0.07[ab]	1.46± 0.05[a]	2.09 ± 0.04[b]	2.20 ± 0.05[b]
LT11	1.45 ± 0.04[ab]	1.50 ± 0.07[ab]	2.15 ± 0.08[b]	2.27 ± 0.06[bc]
LT12	1.47 ± 0.03[ab]	1.50 ± 0.06[ab]	2.16 ± 0.04[b]	2.26 ± 0.05[bc]
Composting (without worms)				
CT13	1.41± 0.08[a]	1.24± 0.07[a]	1.39± 0.02[a]	1.55 ± 0.05[a]
CT14	1.48 ± 0.05[b]	1.37 ± 0.06[a]	1.72 ± 0.08[a]	1.82 ± 0.07[b]
CT15	1.42± 0.07[a]	1.32± 0.05[a]	1.65 ± 0.04[a]	1.71 ± 0.05[a]
CT16	1.45± 0.07[ab]	1.35± 0.07[a]	1.70 ± 0.05[b]	1.70 ± 0.07[b]
CT17	1.45 ± 0.04[ab]	1.39 ± 0.05[ab]	1.73 ± 0.09[b]	1.72 ± 0.07[bc]
CT18	1.47 ± 0.03[ab]	1.41± 0.09[ab]	1.75 ± 0.07[b]	1.70 ± 0.03[bc]

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 5. TP (%) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	TP (%) Days 0	25	50	75
Perionyx ceylanensis				
PT1	0.32± 0.08[a]	0.36± 0.09[a]	0.56 ± 0.11[a]	0.67 ± 0.09[a]
PT2	0.92± 0.07[c]	0.99± 0.11[b]	1.42 ± 0.09[c]	1.53 ± 0.04[c]
PT3	0.86± 0.11[b]	0.90± 0.05[b]	1.09 ± 0.07[b]	1.28 ± 0.11[b]
PT4	0.92± 0.05[c]	0.97± 0.14[b]	1.18 ± 0.13[c]	1.51 ± 0.08[c]
PT5	0.93± 0.13[c]	1.05± 0.16[c]	1.35 ± 0.15[d]	1.81 ± 0.07[d]
PT6	0.92 ± 0.06[c]	1.05 ± 0.12[c]	1.39 ± 0.12[d]	1.85 ± 0.14[d]
Lampito mauritii				
LT7	0.32± 0.08[a]	0.35± 0.11[a]	0.47 ± 0.10[a]	0.71 ± 0.11[a]
LT8	0.92± 0.07[c]	0.96± 0.15[b]	1.15 ± 0.05[c]	1.29 ± 0.14[c]
LT9	0.86± 0.11[b]	0.89± 0.08[b]	0.91 ± 0.09[b]	1.12 ± 0.09[b]
LT10	0.92± 0.05[c]	0.95± 0.12[b]	1.12 ± 0.16[c]	1.29 ± 0.06[c]
LT11	0.93± 0.13[c]	0.99± 0.08[b]	1.27 ± 0.11[d]	1.42 ± 0.13[d]
LT12	0.92 ± 0.06[c]	1.02 ± 0.05[bc]	1.29 ± 0.10[d]	1.45 ± 0.11[d]
Composting (without worms)				
CT13	0.32± 0.08[a]	0.33± 0.12[a]	0.39 ± 0.09[a]	0.41 ± 0.13[a]
CT14	0.92± 0.07[c]	0.95± 0.10[b]	0.92 ± 0.07[c]	0.99 ± 0.08[b]
CT15	0.86± 0.11[b]	0.89± 0.05[b]	0.72 ± 0.12[b]	0.90 ± 0.07[b]
CT16	0.92± 0.05[c]	0.95± 0.13[c]	0.96 ± 0.15[c]	0.98 ± 0.09[b]
CT17	0.93± 0.13[c]	0.96± 0.07[c]	0.99 ± 0.11[c]	1.05 ± 0.08[c]
CT18	0.92 ± 0.06[c]	0.96 ± 0.06[c]	0.99 ± 0.17[c]	1.05. ± 0.10[c]

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 6. TK (%) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	TK (%) Days			
	0	25	50	75
		Perionyx ceylanensis		
PT1	1.35±0.03	1.43 ± 0.12 [a]	1.69 ± 0.18 [a]	1.71 ± 0.09 [a]
PT2	0.81±0.02	1.49 ± 0.15 [a]	1.95 ± 0.15 [b]	2.24 ± 0.11 [c]
PT3	1.12±0.08	1.44 ± 0.08 [a]	1.72 ± 0.12 [ab]	1.85 ± 0.08 [b]
PT4	1.15±0.11	1.49 ± 0.09 [a]	2.18 ± 0.10 [c]	2.25 ± 0.15 [c]
PT5	1.18±0.09	1.50 ± 0.13 [a]	2.21 ± 0.17 [c]	2.31 ± 0.07 [c]
PT6	1.19±0.16	1.51 ± 0.15 [a]	2.23 ± 0.15 [c]	2.33 ± 0.11 [c]
		Lampito mauritii		
LT7	1.35±0.03	1.40 ± 0.14 [a]	1.60 ± 0.10 [a]	1.71 ± 0.06 [a]
LT8	0.81±0.02	1.48 ± 0.11 [a]	1.92 ± 0.17 [b]	2.24 ± 0.15 [c]
LT9	1.12±0.08	1.43 ± 0.09[a]	1.69 ± 0.09 [ab]	1.85 ± 0.12 [b]
LT10	1.15±0.11	1.46 ± 0.13[a]	2.09 ± 0.08 [c]	2.25 ± 0.07 [c]
LT11	1.18±0.09	1.50 ± 0.11 [a]	2.15 ± 0.07 [c]	2.31 ± 0.14 [c]
LT12	1.19±0.16	1.50 ± 0.12 [a]	2.16 ± 0.11[c]	2.33 ± 0.08 [c]
		Composting (without worms)		
CT13	1.35±0.03	1.37 ± 0.10 [b]	1.39 ± 0.15[b]	1.55 ± 0.08 [b]
CT14	0.81±0.02	0.95 ± 0.11 [a]	1.05 ± 0.13[a]	1.32 ± 0.11 [a]
CT15	1.12±0.08	1.32 ± 0.07[b]	1.65 ± 0.05 [c]	1.71 ± 0.10 [b]
CT16	1.15±0.11	1.35 ± 0.10[b]	1.70 ± 0.07 [d]	1.70 ± 0.15[c]
CT17	1.18±0.09	1.39 ± 0.14 [b]	1.73 ± 0.12 [d]	1.70 ± 0.08 [c]
CT18	1.19±0.16	1.41 ± 0.11 [bc]	1.75 ± 0.10[d]	1.70 ± 0.07[c]

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 7. C: N ratio during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	C:N Days			
	0	25	50	75
		Perionyx ceylanensis		
PT1	28.8±0.12	28.1±0.05	18.7±0.21	12.7±0.18[c]
PT2	31.9±0.24	30.5±0.11	14.5±0.38	9.2±0.24[ab]
PT3	30.9±0.09	30.2±0.17	16.0±0.15	10.5±0.38[b]
PT4	27.0±0.17	27.5±0.21	11.7±0.22	8.3±0.33[ab]
PT5	23.8±0.20	23.0±0.11	10.6±0.30	6.8±0.15[a]
PT6	23.9±0.19	23.1±0.29	11.9±0.09	7.9±0.18[a]
		Lampito mauritii		
LT7	28.8±0.12	29.2±0.20	20.9±0.09	12.9±0.20[c]
LT8	31.9±0.24	32.2±0.24	15.9±0.11	9.5±0.34[ab]
LT9	30.9±0.09	32.5±0.15	17.5±0.15	10.9±0.12[b]
LT10	27.0±0.17	27.3±0.11	13.2±0.08	8.9±0.09[b]
LT11	23.8±0.20	23.7±0.17	11.8±0.11	7.4±0.15[a]
LT12	23.9±0.19	24.3±0.07	13.2±0.21	8.5±0.14[b]
		Composting (without worms)		
CT13	28.8±0.12	33.2±0.08	29.2±0.12	25.5±0.12[b]
CT14	31.9±0.24	36.2±0.21	22.5±0.18	20.7±0.09[a]
CT15	30.9±0.09	36.7±0.14	23.3±0.21	21.1±0.07[a]
CT16	27.0±0.17	31.2±0.22	22.0±0.07	21.4±0.11[a]
CT17	23.8±0.20	29.6±0.16	21.5±0.20	20.8±0.20[a]
CT18	23.9±0.19	30.0±0.10	21.4±0.27	20.4±0.14[a]

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 8. Na (mg kg^{-1}) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	Na (mgkg^{-1})			
	Days			
	0	25	50	75
Perionyx ceylanensis				
PT1	215.24±0.22	223.21±0.19	228.17±0.24	232.42±0.35^{a}
PT2	190.21±0.13	210.35±0.24	227.21±0.35	239.15±0.19^{a}
PT3	195.38±0.21	227.28±0.25	231.35±0.21	242.52±0.15^{a}
PT4	198.19±0.27	229.43±0.19	232.18±0.19	245.18±0.24^{a}
PT5	202.22±0.31	230.43±0.31	241.22±0.24	261.37±0.31^{b}
PT6	205.15±0.24	230.20±0.30	243.19±0.28	263.29±0.26^{b}
Lampito mauritii				
LT7	215.24±0.22	225.18±0.25	229.21±0.32	230.19±0.15^{a}
LT8	190.21±0.13	215.29±0.17	225.18±0.21	239.27±0.19^{a}
LT9	195.38±0.21	225.44±0.19	232.35±0.37	240.19±0.21^{a}
LT10	198.19±0.27	230.15±0.25	230.29±0.19	246.25±0.18^{ab}
LT11	202.22±0.31	234.53±0.31	243.47±0.35	260.27±0.24^{b}
LT12	205.15±0.24	235.29±0.22	245.41±0.17	263.31±0.32^{b}
Composting (without worms)				
CT13	215.24±0.22	220.18±0.25	225.22±0.22	227.23±0.21^{a}
CT14	190.21±0.13	212.42±0.18	217.35±0.31	221.24±0.19^{a}
CT15	195.38±0.21	219.29±0.31	222.29±0.42	227.52±0.31^{a}
CT16	198.19±0.27	225.17±0.24	224.18±0.18	229.49±0.20^{a}
CT17	202.22±0.31	227.32±0.19	224.31±0.25	233.35±0.28^{ab}
CT18	205.15±0.24	227.21±0.16	226.45±0.20	233.41±0.15^{ab}

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 9. Ca (mgkg^{-1}) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	Ca (mgkg^{-1})			
	Days			
	0	25	50	75
Perionyx ceylanensis				
PT1	285.21±0.52	289.24 ± 0.20^{a}	295.45 ± 0.30^{a}	303.32 ± 0.46^{a}
PT2	198.21±0.28	299.24 ± 0.30^{a}	315.35 ± 0.24^{b}	325.18 ± 0.51^{b}
PT3	220.24±0.45	28034 ± 0.31^{a}	308.27 ± 0.42^{b}	319.28 ± 0.50^{ab}
PT4	260.36±0.32	295.37 ± 0.25^{a}	330.28 ± 0.35^{c}	339.55 ± 0.30^{c}
PT5	278.47±0.51	299.17 ± 0.21^{a}	341.42 ± 0.29^{c}	350.19 ± 0.28^{d}
PT6	282.52±0.17	299.45 ± 0.30^{a}	345.51 ± 0.40^{cd}	351.62 ± 0.45^{d}
Lampito mauritii				
LT7	285.21±0.52	289.42 ± 0.25^{ab}	292.35 ± 0.25^{a}	299.25 ± 0.41^{a}
LT8	198.21±0.28	299.41 ± 0.19^{b}	307.49 ± 0.21^{b}	318.31 ± 0.18^{b}
LT9	220.24±0.45	279.24 ± 0.17^{a}	305.51 ± 0.32^{b}	299.18 ± 0.52^{a}
LT10	260.36±0.32	290.28 ± 0.21^{ab}	325.27 ± 0.19^{c}	320.27 ± 0.3^{b}
LT11	278.47±0.51	295.31 ± 0.15^{ab}	339.31 ± 0.15^{c}	335.49 ± 0.19^{c}
LT12	282.52±0.17	295.28 ± 0.22^{ab}	340.19 ± 0.31^{c}	335.25 ± 0.25^{c}
Composting (without worms)				
CT13	285.21±0.52	285.17 ± 0.28^{b}	289.21 ± 0.25^{ab}	291.19 ± 0.45^{a}
CT14	198.21±0.28	299.25± 0.21^{b}	301.18 ± 0.21^{c}	305.25 ± 0.15^{b}
CT15	220.24±0.45	280.35 ± 0.15^{a}	286.27 ± 0.32^{ab}	289.18 ± 0.31^{a}
CT16	260.36±0.32	259.25 ± 0.11^{a}	275.31 ± 0.19^{a}	299.32 ± 0.35^{b}
CT17	278.47±0.51	265.41 ± 0.19^{ab}	299.45 ± 0.15^{c}	305.27 ± 0.27^{c}
CT18	282.52±0.17	265.37 ± 0.07^{ab}	299.25 ± 0.31^{c}	307.41 ± 0.20^{c}

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

Table 10. Mg (mg kg^{-1}) during vermicomposting and composting of the CP and SPM in different treatments.

Treatments	Mg (mgkg^{-1})			
	Days			
	0	25	50	75
Perionyx ceylanensis				
PT1	175.54±0.41	182.41±0.55	191.45±0.55	199.32±0.54^{a}
PT2	207.25±0.35	211.29±0.67	235.19±0.29	255.18±0.23^{b}
PT3	185.65±0.42	190.42±0.41	208.36±0.41	259.40±0.67^{b}
PT4	190.24±0.75	198.19±0.38	230.22±0.36	250.25±0.19^{b}
PT5	191.52±0.36	203.35±0.69	245.29±0.58	272.54±0.56^{c}
PT6	195.37±0.24	209.51±0.71	247.55±0.43	275.31±0.29^{c}
Lampito mauritii				
LT7	175.54±0.41	289.42±0.35	292.32±0.55	299.25±0.58^{a}
LT8	207.25±0.35	303.39±0.24	307.49±0.48	310.31±0.91^{b}
LT9	185.65±0.42	279.45±0.57	305.51±0.42	299.18±0.64^{a}
LT10	190.24±0.75	290.27±0.45	325.27±0.39	313.27±0.24^{b}
LT11	191.52±0.36	295.36±0.68	339.31±0.61	335.49±0.98^{c}
LT12	195.37±0.24	295.51±0.27	340.19±0.90	335.25±0.46^{c}
Composting (without worms)				
CT13	175.54±0.41	285.17±0.28	289.21±0.65	291.19±0.52^{a}
CT14	207.25±0.35	299.25±0.35	301.18±0.45	305.25±0.35^{ab}
CT15	185.65±0.42	280.35±0.45	286.27±0.84	289.18±0.48^{a}
CT16	190.24±0.75	229.25±0.39	275.31±0.77	299.32±0.64^{a}
CT17	191.52±0.36	265.41±0.24	299.45±0.39	305.27±0.19^{ab}
CT18	195.37±0.24	265.37±0.64	299.29±0.45	307.41±0.41^{ab}

Above values are reported as mean ± standard deviation among three replicates; Different letters in a row are significant at *P<0.05* (ANOVA; Tukey's test).

DISCUSSION

The total organic C in vermicompost includes forms of organic matter at different stages of degradation, some resistant to further decomposition and some remaining biologically active. The combined action of earthworms and microorganisms may be responsible for TOC loss from the initial feed waste in the form of CO_2. Similar results have been reported by Manivannan (2005) during vermicomposting of sugar industry waste. In the present study, TOC content was lesser in all the vermicompost than initial TOC. Thus, combined action earthworms and microorganisms bring about C loss from the substrates in the form of CO_2. The observed results are supported by those of Khwairakpam and Bhargava, 2009, who have reported loss of carbon 20–45% as CO_2 during vermicomposting of industrial wastes. The increasing trend in TN content during vermicomposting corroborates with the findings of other researchers (Suthar and Singh, 2008; Khwairakpam and Bhargava, 2009). Suthar (2009) recommended that the bulking materials modify the physical structure of waste and also accelerate the waste mineralization rate in vermibeds. In support of the above observations in the present study the nitrogen was more in all initial substrates and after vermicomposting in the treatments which are having in SPM. However, nitrogen enrichment pattern mainly depends upon the total amount of N present in the feed material/organic supplements and the extent of mineralization (Adi and Noor, 2009).

In the present study, the increasing trend in TP content during vermicomposting is consistent with the findings of other researchers (Manivannan, 2005). Sharma *et al.*, (2017) reported that the increase in TP content during vermicomposting is probably through mineralization, release and mobilization of available P content from organic waste. The differences in the results of TK can be attributed to the differences in the chemical nature of the initial substrate materials. Kaviraj and Sharma (2003) found that enhanced number of micro-flora present in the gut of earthworms might have played an important role in the process and increased potassium content during vermicomposting process. Suthar (2009) has also suggested that earthworm processed waste material contains higher concentration of exchangeable K due to enhanced microbial activity during the vermicomposting process, which consequently enhances the rate of mineralization. It has been suggested that earthworm processed material contains higher concentration of TK as compared to the feed material due to higher mineralization rate as a result of enhanced microbial and enzyme activities in the guts of earthworms (Manivannan, 2005). From the results, it may be concluded that the rate of mineralization could be decreased due to the absence of organic supplements with CP.

In the present study, the lowest C:N ratio after vermicomposting was in the treatments containing CP and SPM in appropriate proportions. In most of earlier reports a decrease in C:N ratio was recorded during vermicomposting (Gupta and Garg, 2008). The decrease in C:N ratio and relative increase in the TN of vermicompost may also be due to the loss of dry mass in terms of CO_2 as well as moisture loss through evaporation during vermicomposting process. Therefore, prominent degree of organic matter stabilization of CP amended with SPM (source of nitrogen, in order to make the waste mixture appropriate for breakdown using earthworms) was achieved in all the treatments which prove that *P. ceylanensis* and *L. mauritii* can promote decomposition and mineralization of organic matter. The worm inoculated treatments showed more concentration of available forms of Ca, Mg, and Na than experimental control (natural composting). The maximum increase in Ca, Mg, and Na was observed on 60th day and slightly decline on 90th day of vermicomposting. As a result, the worm inoculated treatments plays an important role in microbial- mediated nutrient mineralization in wastes. In general, microorganism plays an important role in transformation of plant metabolites into more available forms of Ca, Mg, and Na content, which can be further metabolized by microbial communities associated with compost (Dominguez and Edwards, 2004).

CONCLUSION

Hence, it was concluded that the possibility of CP amended with bulking agent SPM waste decomposition by *P. ceylanensis* and *L. mauritii* has been evaluated in order to rapid composting and to produce quality compost with higher agronomic value. The decomposition of the waste materials was enhanced, as indicated by reduction in C:N ratios, in the presence of earthworms than natural composting. Our results established that after the adding of CP in appropriate quantities (less than 60%) to the SPM, it can be used as a raw material in the vermicomposting using both worms.

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REFERENCES

Adi, A.J. and Noor, Z.M., 2009. Waste recycling: Utilization of coffee grounds and kitchen waste in vermicomposting. *Bioresour. Technol.*, 100, 1027-1030.

Dominguez, J. and Edwards C.A., 2004. Vermicomposting organic wastes: A review. In: Shakir Hanna, S.H., Mikhail W.Z.A. (Eds) Soil Zoology for sustainable Development in the 21st century, Cairo, pp. 369-395.

Garg, V.K., Kaushik, P. and Dilbaghi, N., 2005. Vermicomposting of wastewater sludge from textile mill spiked with anaerobically digested biogas plant slurry employing *Eisenia fetida. Ecotoxicol. Environ. Saf.*, 65(3), 412-419.

Gupta, R. and Garg, V.K., 2008. Stabilization of primary sewage sludge during vermicomposting. *J. Hazard. Mater.*, 162, 430-439.

Jackson, M.L., 1973. Soil Chemical Analysis. Prentice Hall of India, New Delhi.

Kaviraj and Sharma, S. 2003. Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresour. Technol.*, 90, 169-173.

Khwairakpam, M. and Bhargava, R., 2009. Bioconversion of filter mud using vermicomposting employing two exotic and one local earthworm species. *Bioresour. Technol.*, 100, 5846-5852.

Manivannan, S., 2005. Standardization and nutrient analysis of vermicomposting sugarcane wastes, press mud-trash-bagasse by *Lampito mauritii* and *Perioynx excavatus* and the effects of vermicompost on soil fertility and crop productivity, Ph.D. Dissertation, Annamalai University, Annamalainagar, Tamil Nadu, India.

Pandey, A., Soccol, C.R., Nigam, P., Soccol, V.T., Vandenberghe, L.P.S. and Mohan, R., 2000. Biotechnological potential of agro-industrial residues. II: cassava bagasse. *Bioresour. Technol.*, 74(1), 81-87.

Pushpa S.M. and Manonmani, H.K., 2008. Bioconversion of Coffee Industry Wastes with White Rot Fungus *Pleurotus florida*. *Res. J. Environ. Sci.*, 2, 145-150.

Sharma, A., Saha, T.N., Arora, A., Shah, R and Nain, L. 2017. Efficient microorganism compost benefits plant growth and improves soil health in Calendula and Marigold. *Horticult. Plant J.*, 3(2), 67-72.

Suthar, S., 2009. Vermistabilization of municipal sewage sludge amended with sugarcane trash using epigeic *Eisenia fetida* (Oligochaeta). *J. Hazard. Mat.*, 163: 199-206.

Suthar, S. and Singh, S. 2008.Vermicomposting of domestic waste by using two epigeic earthworms (*Perionyx excavates* and *Perionyx sansibaricus*). *Int. J. Envion. Sci. Tecnol.*, 5(1), 99-106.

Tiquia, S.M., 2005., Microbial parameters as indicators of compost maturity. *J. Appl. Microbiol.*, 99, 816-828.