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Efficiency of earthworm *Perionyx ceylanensis* on nutrient enhancement during Vermiconversion of coffee pulp of *Coffea arabica*

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Abstract
Use of non-stabilized organic waste to soil may leads to immobilization of plant nutrients and cause soil pollution and phytotoxicity. Per annum huge amount of coffee by-products are generated throughout coffee processing industry. The environmental problems associated with raw coffee pulp, such as release of inorganic polymers like polyphenols and tannins could be mitigated by stabilizing its nutrient and organic matter contents by vermicomposting before application to agricultural soils. The aim of this work was to evaluate the changes in nutrient content of coffee pulp amended with press mud 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 T4, T5 and T6 treatments showed significantly higher level of nutrients than other treatments and natural composting.

Keywords: nutrients, vermicomposting, *Perionyx ceylanensis***,** coffee pulp

Introduction

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 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. 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) [1]. 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 wastes over attractive recycling alternatives (Pandey *et al.*, 2000; Bhata *et al.*, 2016) [2, 3].

In India, sugar industry 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) [4]. 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) used as amendment, which was mixed with coffee pulp.

Vermiconversion is flourishing method for changing organic solid waste in to manure that is wealthy 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 (Arsalan *et al.*, 2016) [5]. 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 (Mnivannan, 2005; Garg *et al.*,, 2005; Zaremanesh *et al.*, 2017) [5, 6, 7]. 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; Bhata *et al.*, 2016) [8, 3]. 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. Keeping in view of the above facts that the aims of this study were to assess the ability of *P. ceylanencis* to efficiently decompose coffee pulp with press mud to monitoring the nutrient enhancement.

Materials and methods

Selection of collection of coffee pulp (CP), press mud (PM) and *P. ceylanensis*

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 (PM), also called filter mud was procured from E.I.D. Parry's Sugar Mill located at Nellikuppam, Cuddalore District, Tamil Nadu, India. Fresh PM was kept under shade for 3 weeks to remove the foul smell before using for the experimental process. The initial physico-chemical characteristics of CP and PM are given in Table 2. Indigenous earthworm's *P. ceylanensis* 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 vermiculture.

Experimental design and nutrient analysis

In the present study, different proportions of Coffee pulp (CP) with bulking material Sugar industry press mud (PM) mixtures were prepared (Table 1). Coffee pulp (CP) and Sugar industry press mud (PM) was weighed (dry weight) in the above said description and mixed well with 65-75% moisture content. The waste mixtures, CP and PM 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 PM 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 PM with *P. ceylanensis*. Treatments of CT13, CT14, CT15, CT16, CT17 and CT18 were composed of different proportions of CP and PM 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, and 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 species were weighed and inoculated in to respective each treatment (Manivannan *et al.*, 2005) [4].
Samples were collected periodically from each treatment for nutrient analysis. Total organic carbon content in the sample was determined by chromic oxidation method (Walkely and Black, 1934) [9]. Furthermore total Kjeldhal nitrogen was measured by micro Kjeldhal method. Total phosphorus was estimated by vanadomolybdo phosphoric acid yellow colour method using a colorimeter (Model 115, Systronics, India) (Jackson, 1973) [10]. While Total potassium was detected by the method of Jackson (1973) [10] 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 ion method. 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.

Table 1: Description of different treatments with coffee pulp and press mud used for experimentations

Treatments	Coffee Pulp (CP)	Press Mud (PM)
Perionyx ceylanensis		
T1	CP 100%	PM 0%
T2	CP 0%	PM 100%
T3	CP 80%	PM 20%
T4	CP 60%	PM 40%
T5	CP 40%	PM 60%
T6	CP 20%	PM 80%
Composting(without worms)		
CT1	CP 100%	PM 0%
CT2	CP 0%	PM 100%
CT3	CP 80%	PM 20%
CT4	CP 60%	PM 40%
CT5	CP 40%	PM 60%
CT6	CP 20%	PM 80%

CP- Coffee Pulp; PM- Press mud; PT – Treatments with *Perionyx ceylanensis*; CT - Composting without earthworms.

Results and discussion

In the present study, CP and PM used in this study were analyzed prior to natural composting and vermicomposting and their initial values are given in the Table 2. Total organic carbon (TOC) decreased in all treatments after vermicomposting process, considerably in those treatments which contained up to 60% CP with PM. At the end of experiment, the final TOC of vermicompost was lesser than initial organic matter content. Further, TOC content was lesser in vermicompost of all the treatments especially, T4, T5 and T6 showed significant *($p < 0.05$)* reduction in TOC contents by the end of vermicomposting than other treatments and natural composting (Table 3). 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) [4] 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 [11], who have reported loss of carbon significantly as CO_2 during vermicomposting of industrial wastes. The TKN (%) content of the vermicompost varied for *P.ceylanensis* (Table 4) and increase in TKN content during vermicomposting was in the range of 27.5 to 132.4% for *P.ceylanensis*. The increasing trend in TN content during vermicomposting corroborates with the findings of other researchers (Suthar and Singh, 2008; Khwairakpam and Bhargava, 2009; Bhata *et al.*, 2016) [12, 11, 3]. Suthar (2009) [13] recommended that the bulking materials modify the physical structure of waste and also accelerate the waste mineralization rate in vermicomposting. 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 PM. 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; Dandotiya and Agrawal, 2015) [14, 15].

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). In the present study, the lowest C:N ratio after vermicomposting was in the treatments containing CP and PM 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 PM (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* can promote decomposition and mineralization of organic matter. At the end of experiment total phosphorous (TP) content of the vermicompost produced from different treatments of *P.ceylanensis* was considerably increased as compared to the initial substrate and natural compost (Table 5). In the present study, the increasing trend in TP content during vermicomposting is consistent with the findings of other researchers (Manivannan, 2005) [4]. Sharma *et al.*, (2017) [16] have reported that the increase in TP content during vermicomposting is probably through mineralization, release and mobilization of available P content from organic waste. In this study, the TK (%) content for initial substrate material was in the range from 0.81±0.02 to 1.35±0.03 and the TK content of the vermicompost varied from 1.71±0.09 to 2.33±0.11 at the end (Table 6). 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) [17] and Dandotiya and Agrawal, 2015 [15] 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) [4]. From the results, it may be concluded that the rate of mineralization could be decreased due to the absence of organic supplements with CP.

The level of micro nutrients Ca, Mg and Na of vermicompost produced by *P.ceylanensis* showed significant difference in all the treatments (Table 8, 9 and 10). However, T4, T5 and T6 treatments showed significantly ($p<0.05$) higher level of micro nutrients than other treatments and natural composting treatments. 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, T4, T5 and T6 treatments showed significantly *($p<0.05$)* higher level of macro and micro nutrients than other treatments and natural composting. 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 (Dandotiya and Agrawal, 2015) [15]. 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; Arsalan *et al*., 2016; Zaremanesh *et al.*, 2017) [18, 5, 7].

Table 2: Initial physico-chemical characterizations of the CP and PM

Parameters	TOC	TKN	TP	TK	Na	Ca	Mg	C:Nratio
	(%)				(mg kg^{-1})			
CP	41.14±0.50	0.98±0.07	0.32±0.05	0.91±0.11	219±0.42	375±0.52	178±0.19	41.8±0.5
PM	54.4±0.25	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: Reduction of TOC during vermicomposting and composting of the CP and PM in different treatments

Treatments	TOC (%)			
	Days			
	0	25	50	75
Perionyx ceylanensis				
T1	39.5 ± 0.23^{a}	40.8 ± 0.29^{a}	31.6 ± 0.18^{b}	21.9 ± 0.29^{ab}
T2	47.2 ± 0.32^{b}	48.5 ± 0.30^{b}	28.2 ± 0.29^{b}	20.6 ± 0.35^{ab}
T3	43.5 ± 0.19^{ab}	45.6 ± 0.19^{ab}	27.6 ± 0.35^{ab}	19.5 ± 0.19^{ab}
T4	39.7 ± 0.21^{ab}	40.5 ± 0.21^{ab}	25.5 ± 0.17^{ab}	18.7 ± 0.34^{a}
T5	33.8 ± 0.35^{a}	34.8 ± 0.35^{a}	23.4 ± 0.41^{a}	15.6 ± 0.25^{a}
T6	34.8 ± 0.74^{a}	39.9 ± 0.74^{a}	26.5 ± 0.49^{a}	18.5 ± 0.16^{a}

Composting (without worms)				
CT1	39.5 ± 0.18[a]	41.2 ± 0.22[a]	40.6 ± 0.18[a]	39.5 ± 0.50[ab]
CT2	47.2 ± 0.29[b]	49.6 ± 0.17[b]	38.7 ± 0.25	37.7 ± 0.29[ab]
CT3	43.5 ± 0.20[ab]	48.5 ± 0.35[ab]	38.5 ± 0.35[ab]	37.6 ± 0.45[ab]
CT4	39.7 ± 0.35[ab]	42.1 ± 0.29[ab]	37.4 ± 0.40[ab]	36.5 ± 0.27[a]
CT5	33.8 ± 0.19[a]	41.2 ± 0.49[a]	37.2 ± 0.51[a]	35.1 ± 0.31[a]
CT6	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*.

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

Treatments	TKN (%)			
	Days			
	0	25	50	75
Perionyx ceylanensis				
T1	1.41± 0.08[a]	1.43± 0.09[a]	1.69± 0.02[a]	1.71 ± 0.11[a]
T2	1.48 ± 0.05[b]	1.49 ± 0.06[a]	1.75 ± 0.04[a]	2.24 ± 0.08[b]
T3	1.42± 0.07[a]	1.44± 0.04[a]	1.72 ± 0.05[a]	1.85 ± 0.09[a]
T4	1.45± 0.07[ab]	1.49± 0.05[a]	2.18 ± 0.03[b]	2.25 ± 0.07[b]
T5	1.45 ± 0.04[ab]	1.50 ± 0.06[ab]	2.21 ± 0.05[b]	2.31 ± 0.05[bc]
T6	1.47 ± 0.03[ab]	1.51 ± 0.05[ab]	2.23 ± 0.04[b]	2.33 ± 0.04[bc]
Composting (without worms)				
CT1	1.41± 0.08[a]	1.24± 0.07[a]	1.39± 0.02[a]	1.55 ± 0.05[a]
CT2	1.48 ± 0.05[b]	1.37 ± 0.06[a]	1.72 ± 0.08[a]	1.82 ± 0.07[b]
CT3	1.42± 0.07[a]	1.32± 0.05[a]	1.65 ± 0.04[a]	1.71 ± 0.05[a]
CT4	1.45± 0.07[ab]	1.35± 0.07[a]	1.70 ± 0.05[b]	1.70 ± 0.07[b]
CT5	1.45 ± 0.04[ab]	1.39 ± 0.05[ab]	1.73 ± 0.09[b]	1.72 ± 0.07[bc]
CT6	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*.

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

Treatments	TP (%)			
	Days			
	0	25	50	75
Perionyx ceylanensis				
T1	0.32± 0.08[a]	0.36± 0.09[a]	0.56 ± 0.11[a]	0.67 ± 0.09[a]
T2	0.92± 0.07[c]	0.99± 0.11[b]	1.42 ± 0.09[c]	1.53 ± 0.04[c]
T3	0.86± 0.11[b]	0.90± 0.05[b]	1.09 ± 0.07[b]	1.28 ± 0.11[b]
T4	0.92± 0.05[c]	0.97± 0.14[b]	1.18 ± 0.13[c]	1.51 ± 0.08[c]
T5	0.93± 0.13[c]	1.05± 0.16[c]	1.35 ± 0.15[d]	1.81 ± 0.07[d]
T6	0.92 ± 0.06[c]	1.05 ± 0.12[c]	1.39 ± 0.12[d]	1.85 ± 0.14[d]
Composting (without worms)				
CT1	**0.32± 0.08[a]**	**0.33± 0.12[a]**	**0.39 ± 0.09[a]**	**0.41 ± 0.13[a]**
CT2	0.92± 0.07[c]	0.95± 0.10[b]	0.92 ± 0.07[c]	0.99 ± 0.08[b]
CT3	0.86± 0.11[b]	0.89± 0.05[b]	0.72 ± 0.12[b]	0.90 ± 0.07[b]
CT4	0.92± 0.05[c]	0.95± 0.13[c]	0.96 ± 0.15[c]	0.98 ± 0.09[b]
CT5	0.93± 0.13[c]	0.96± 0.07[c]	0.99 ± 0.11[c]	1.05 ± 0.08[c]
CT6	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 PM in different treatments

Treatments	TK (%)			
	Days			
	0	25	50	75
Perionyx ceylanensis				
T1	1.35±0.03	1.43 ± 0.12[a]	1.69 ± 0.18[a]	1.71 ± 0.09[a]
T2	0.81±0.02	1.49 ± 0.15[a]	1.95 ± 0.15[b]	2.24 ± 0.11[c]
T3	1.12±0.08	1.44 ± 0.08[a]	1.72 ± 0.12[ab]	1.85 ± 0.08[b]
T4	1.15±0.11	1.49 ± 0.09[a]	2.18 ± 0.10[c]	2.25 ± 0.15[c]
T5	1.18±0.09	1.50 ± 0.13[a]	2.21 ± 0.17[c]	2.31 ± 0.07[c]
T6	1.19±0.16	1.51 ± 0.15[a]	2.23 ± 0.15[c]	2.33 ± 0.11[c]
Composting (without worms)				
CT1	**1.35±0.03**	**1.37 ± 0.10[b]**	**1.39 ± 0.15[b]**	**1.55 ± 0.08[b]**
CT2	0.81±0.02	0.95 ± 0.11[a]	1.05 ± 0.13[a]	1.32 ± 0.11[a]
CT3	1.12±0.08	1.32 ± 0.07[b]	1.65 ± 0.05[c]	1.71 ± 0.10[b]
CT4	1.15±0.11	1.35 ± 0.10[b]	1.70 ± 0.07[d]	1.70 ± 0.15[c]
CT5	1.18±0.09	1.39 ± 0.14[b]	1.73 ± 0.12[d]	1.70 ± 0.08[c]
CT6	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*.

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

Treatments	C:N			
	Days			
	0	25	50	75
Perionyx ceylanensis				
T1	28.8±0.12	28.1±0.05	18.7±0.21	12.7±0.18[c]
T2	31.9±0.24	30.5±0.11	14.5±0.38	9.2±0.24[ab]
T3	30.9±0.09	30.2±0.17	16.0±0.15	10.5±0.38[b]
T4	27.0±0.17	27.5±0.21	11.7±0.22	8.3±0.33[ab]
T5	23.8±0.20	23.0±0.11	10.6±0.30	6.8±0.15[a]
T6	23.9±0.19	23.1±0.29	11.9±0.09	7.9±0.18[a]
Composting (without worms)				
CT1	28.8±0.12	33.2±0.08	29.2±0.12	25.5±0.12[b]
CT2	31.9±0.24	36.2±0.21	22.5±0.18	20.7±0.09[a]
CT3	30.9±0.09	36.7±0.14	23.3±0.21	21.1±0.07[a]
CT4	27.0±0.17	31.2±0.22	22.0±0.07	21.4±0.11[a]
CT5	23.8±0.20	29.6±0.16	21.5±0.20	20.8±0.20[a]
CT6	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*.

Table 8: Na (mg kg-1) during vermicomposting and composting of the CP and PM in different treatments

Treatments	Na (mgkg^{-1}) Days			
	0	25	50	75
Perionyx ceylanensis				
T1	215.24±0.22	223.21±0.19	228.17±0.24	232.42±0.35^{a}
T2	190.21±0.13	210.35±0.24	227.21±0.35	239.15±0.19^{a}
T3	195.38±0.21	227.28±0.25	231.35±0.21	242.52±0.15^{a}
T4	198.19±0.27	229.43±0.19	232.18±0.19	245.18±0.24^{a}
T5	202.22±0.31	230.43±0.31	241.22±0.24	261.37±0.31^{b}
T6	205.15±0.24	230.20±0.30	243.19±0.28	263.29±0.26^{b}
Composting (without worms)				
CT1	215.24±0.22	220.18±0.25	225.22±0.22	227.23±0.21^{a}
CT2	190.21±0.13	212.42±0.18	217.35±0.31	221.24±0.19^{a}
CT3	195.38±0.21	219.29±0.31	222.29±0.42	227.52±0.31^{a}
CT4	198.19±0.27	225.17±0.24	224.18±0.18	229.49±0.20^{a}
CT5	202.22±0.31	227.32±0.19	224.31±0.25	233.35±0.28^{ab}
CT6	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 $P<0.05$.

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

Treat-ments	Ca (mgkg^{-1}) Days			
	0	25	50	75
Perionyx ceylanensis				
T1	285.21±0.52	289.24 ± 0.20^{a}	295.45 ± 0.30^{a}	303.32 ± 0.46^{a}
T2	198.21±0.28	299.24 ± 0.30^{a}	315.35 ± 0.24^{b}	325.18 ± 0.51^{b}
T3	220.24±0.45	28034 ± 0.31^{a}	308.27 ± 0.42^{b}	319.28 ± 0.50^{ab}
T4	260.36±0.32	295.37 ± 0.25^{a}	330.28 ± 0.35^{c}	339.55 ± 0.30^{c}
T5	278.47±0.51	299.17 ± 0.21^{a}	341.42 ± 0.29^{c}	350.19 ± 0.28^{d}
T6	282.52±0.17	299.45 ± 0.30^{a}	345.51 ± 0.40^{cd}	351.62 ± 0.45^{d}
Composting (without worms)				
CT1	285.21±0.52	285.17 ± 0.28^{b}	289.21 ± 0.25^{ab}	291.19 ± 0.45^{a}
CT2	198.21±0.28	299.25± 0.21^{b}	301.18 ± 0.21^{c}	305.25 ± 0.15^{b}
CT3	220.24±0.45	280.35 ± 0.15^{a}	286.27 ± 0.32^{ab}	289.18 ± 0.31^{a}
CT4	260.36±0.32	259.25 ± 0.11^{a}	275.31 ± 0.19^{a}	299.32 ± 0.35^{b}
CT5	278.47±0.51	265.41 ± 0.19^{ab}	299.45 ± 0.15^{c}	305.27 ± 0.27^{c}
CT6	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 $P<0.05$.

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

Treatments	Mg (mgkg^{-1}) Days			
	0	25	50	75
Perionyx ceylanensis				
T1	175.54±0.41	182.41±0.55	191.45±0.55	199.32±0.54^{a}
T2	207.25±0.35	211.29±0.67	235.19±0.29	255.18±0.23^{b}
T3	185.65±0.42	190.42±0.41	208.36±0.41	259.40±0.67^{b}
T4	190.24±0.75	198.19±0.38	230.22±0.36	250.25±0.19^{b}
T5	191.52±0.36	203.35±0.69	245.29±0.58	272.54±0.56^{c}
T6	195.37±0.24	209.51±0.71	247.55±0.43	275.31±0.29^{c}
Composting (without worms)				
CT1	175.54±0.41	285.17±0.28	289.21±0.65	291.19±0.52^{a}
CT2	207.25±0.35	299.25±0.35	301.18±0.45	305.25±0.35^{ab}
CT3	185.65±0.42	280.35±0.45	286.27±0.84	289.18±0.48^{a}
CT4	190.24±0.75	229.25±0.39	275.31±0.77	299.32±0.64^{a}
CT5	191.52±0.36	265.41±0.24	299.45±0.39	305.27±0.19^{ab}
CT6	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 $P<0.05$.

Conclusion

Our results established that after the adding of CP in appropriate quantities i.e. less than 60% to the sugar industry waste PM, it can be used as a raw material in the vermicomposting using *P. ceylanensis*. The decomposition of the waste materials was enhanced, as indicated by reduction in C: N ratios, in the presence of earthworms than natural composting. Therefore, it was concluded that the possibility of CP amended with bulking agent PM waste decomposition by local earthworms *P. ceylanensis* has been evaluated in order to rapid composting and to produce quality vermicompost with higher nutrient value.

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