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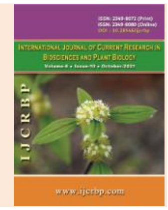

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Biochar and cattle dung amendment for enhanced vermiconversion of mixed leaf litter

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Abstract

A vermicomposting study has been conducted using 15 days of precomposted mixed leaf litter in combination with cow dung (1:1, v/v) and biochar (0, 2, 4, 6 and 8%) employing the earthworm, *Eudrilus eugeniae* for 50 days. During the study, the physicochemical parameters such as pH, electrical conductivity (EC), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total potassium (TP), C/N ratio and C/P ratio were analyzed on 0, 10, 20, 30, 40, and 50 days. The dynamics of physicochemical parameters indicated that the addition of biochar at the rate of 4% yielded the vermicompost with higher nutrient contents than other treatments. The vermicompost obtained from 4% biochar addition recorded 2.15 ± 0.26% TKN, 1.42 ± 0.17% TP and 1.74 ± 0.21% TK while it was 1.69 ± 0.16% TKN, 1.13 ± 0.11% TP and 1.65 ± 0.16% for the substrate without biochar. The TOC, C/N ratio and C/P ratio declined in all the experiments. The C/N ratio in vermicomposts recovered from 0, 2, 4, 6 and 5% were 17.20 ± 1.63, 16.90 ± 1.55, 15.21 ± 1.84, 20.15, ± 2.56 and 24.08 ± 3.23 respectively. The study clearly showed that 4% biochar amendment in vermicomposting of mixed leaf litter and cow dung in a 1:1 ratio is suitable for obtaining vermicompost with higher nutrient contents and desirable properties to be used as an organic soil amendment.

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Introduction

Vermicomposting is considered as one of the green composting technology suitable for the conversion of biowastes originating from agricultural activities, garbage, municipal sludge and agro-based industries (Singh et al., 2020; Yuvaraj et al., 2020). During vermicomposting the organic waste materials are converted by the joint activity of earthworms and microorganisms (Gómez-Brandón et al., 2011). To make the organic materials suitable for vermicomposting, precomposting and addition of different amendment materials are required to be added. In general, most of the organic wastes are mixed with cattle manure for efficient vermiconversion and nutrient-rich vermicompost production (Yuvaraj et al., 2021). Cow dung is added mainly to bring down the C/N ratio and to make the organic substrates palatable to the earthworms. In addition, the amendment materials which are added for enriching the vermicomposting and the final product include mushroom spent straw, microbial biofertilizers, green manure plants, fungal inoculants, and others (Balachandar et al., 2020; Doan et al., 2014; Gong et al., 2019; Karmegam et al., 2021; Negi and Suthar, 2018).

Biochar is an organically rich material produced through the thermochemical biomass conversion process – pyrolysis. Recent studies reveal that biochar is a suitable amendment material for vermicomposting. For example, vegetable waste incorporated with biochar (2.5, 5, and 10%) enhanced the nutrient contents and electrical conductivity apart from attenuating heavy metals and carbon dioxide evolution rate. The addition of biochar during vegetable waste vermicomposting with *Eisenia fetida* shortened the compost stabilization period and enhanced the growth of earthworms (Paul et al., 2020). The biochar derived from bamboo improved the growth and reproduction of earthworms as well as enzymatic activity (Gong et al., 2018). Biochar is efficient additive material for combined composting and vermicomposting which reduced the bioavailability of cadmium and zinc to the earthworms (Malińska et al., 2017).

Though there are several species of earthworms available naturally in soil, only the epigeic category of earthworms is found to be efficient in the bioconversion of organic wastes in the vermicomposting system. The earthworm species like *Eisenia fetida*, *Eudrilus eugeniae*, *Perionyx ceylanensis*, and *Perionyx excavatus* are some of the examples of epigeic earthworms (Biruntha et al., 2020; Karmegam et al., 2019; Paul et al., 2020). In the present study, *Eudrilus eugeniae* - a voracious feeder of organic materials have been used for the vermiconversion of mixed leaf litter substrates. Urban and semi-urban generated tree leaf litter is a large biomass waste either burned or simply dumped as land-fill. Leaf litters ensuing from mango, *Polyalthia longifolia*, *Acacia auriculiformis*, *Grevillea robusta*, *Phyllostachys aurea*, etc. have been utilized for vermicompost generation employing the epigeic earthworms (Karmegam and Daniel, 2008; Prakash and Karmegam, 2010; Singh et al., 2021). The leaf litter generated is most probably of mixed type and segregating plant-wise is time-consuming which is not required in the viewpoint of biomass utilization for value-added product and nutrient recovery. So, the present study has been aimed to utilize mixed leaf litter generated in the college campus in amendment with cow dung and biochar employing the earthworm, *Eudrilus eugeniae*.

Materials and methods

Collection and processing of vermibed substrates

The mixed leaf litter was collected from the college campus and stones, sticks and plastics were removed. Fresh cow dung, free of urine was collected from nearby cattle shed and shade dried for a week and used for the study. The biochar of *Prosopis* was procured from the local market, crushed into powder and stored in air-tight containers until use. The leaf litter and cow dung were mixed in a 1:1 ratio on a dry weight (wt./wt) basis for vermibed preparation. Precomposting is an essential process required to eliminate the initial temperature and to allow the vermicomposting substrates to tender for earthworm and microbial action (Karmegam et al., 2021). Hence, in the present study, the substrate mixtures were subjected to 15 days of precomposting by maintaining 40-50% moisture content. The substrate mixtures were added with different concentrations of biochar (0, 2, 4, 6 and 8%) as shown in Table 1, before precomposting.

Table 1. Vermicomposting treatment design showing the combination of vermibed substrates.

Treatment no.	Treatment combinations (wt/wt)			Biochar (%)
	Mixed leaf litter	Cow dung	Ratio	
V1	50	50	1:1	0
V2	50	50	1:1	2
V3	50	50	1:1	4
V4	50	50	1:1	6
V5	50	50	1:1	8

Vermicomposting

The precomposted substrate mixtures were filled in rectangular plastic containers of uniform size and moistened to hold 70-80% moisture and allowed for 24 h to stabilize. After that, 20 mature clitellate earthworms (*Eudrilus eugeniae*) were added to each treatment. For each treatment triplicates were maintained. The treatments were kept in the environmentally controlled chamber with a temperature of 27 ± 2 °C. The moisture content was maintained by sprinkling water when needed until the end of the vermicomposting, i.e., 50 days.

Physicochemical analysis

The physicochemical characteristics such as pH, electrical conductivity (EC), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP) and total potassium (TK) of vermibed substrates were analyzed on 0, 10, 20, 30, 40 and 50 days of duration. The estimation of pH and EC were done in 10/1 (v/w) water suspension with a digital pH meter and conductivity meter (Systronics), respectively. TOC content was analyzed by the method described by Walkley and Black (Walkley and Black, 1934). TKN, TP and TK contents were estimated according to the method of Jackson (1973) and Tandon (1993). The C/N ratio and C/P ratio were calculated with the values obtained for TKN and TP with that of the TOC content, respectively. The results obtained are expressed as mean ± standard error.

Results and discussion

The results on the dynamics of physicochemical characteristics of vermibed substrates during the process of vermicomposting are shown in Figs. 1 and Fig. 2. The pH, TOC, C/N ratio and C/P ratio showed decline while TKN, TP and TK contents enhanced with variation among the treatments. The pH showed an initial rise followed by a decline in most of the treatments.

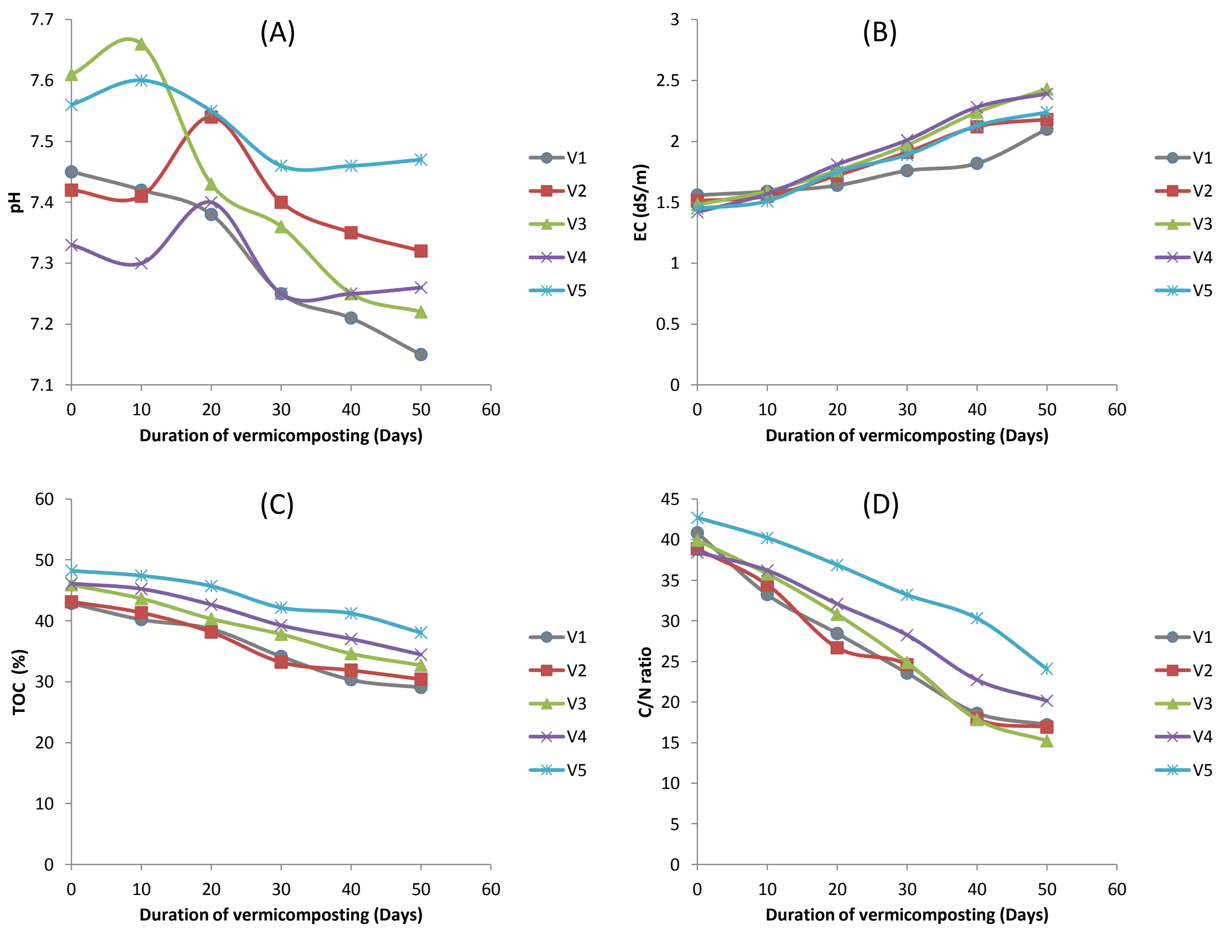

Fig. 1: Dynamics of pH (A), EC (B), TOC (C) and C/N ratio (D) during vermicomposting of mixed leaf litter amended with biochar and cow dung.

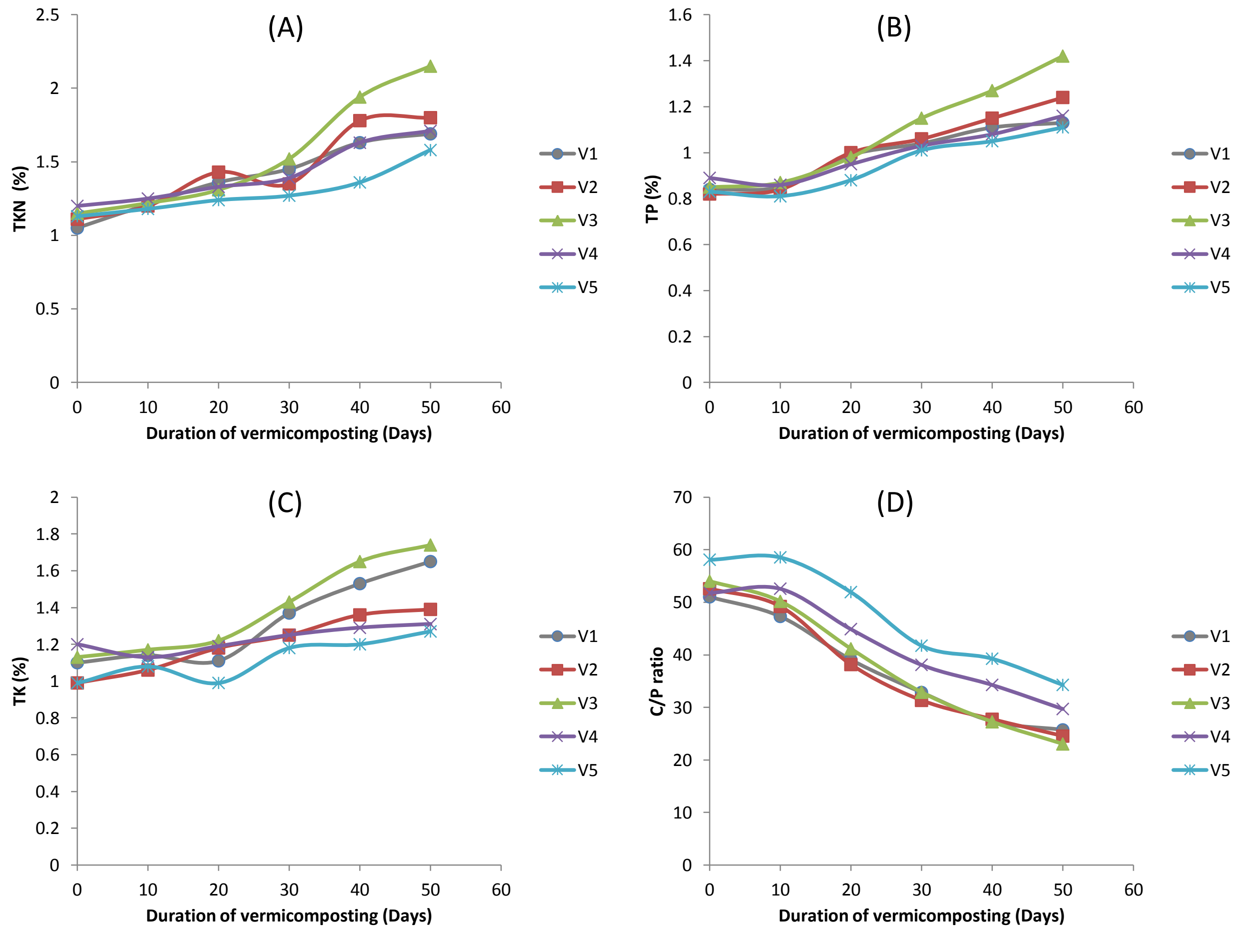

Fig. 2: Dynamics of TKN (A), TP (B), TK (C) and C/P ratio (D) during vermicomposting of mixed leaf litter amended with biochar and cow dung.

The pH range of vermicompost in different treatments was 7.15 – 7.47. The pH change in V3 with 4% biochar was 7.61, 7.66, 7.43, 7.36, 7.25 and 7.22 on day 0, 10, 20, 30, 40 and 50, respectively. A similar change was in the rest of the treatments also. The range of pH in vermicompost was well within the desired range of 7.0–8.5 for agricultural use (Aulinas Masó and Bonmatí Blasi, 2008). The reduction of pH during vermicomposting has been reported by various vermicomposting studies with and without biochar addition (Biruntha et al., 2020; Paul et al., 2020; Suthar et al., 2012). The reduction of pH might have been attributed to the production of organic and phenolic compounds due to the decomposition of organic materials (Gusain and Suthar, 2020; Paul et al., 2020).

The change of EC during vermicomposting showed a steady increase from the initial range of 1.42 – 1.56 dS/m to 2.1 – 2.43 dS/m. A maximum EC was recorded in V3 followed by V4 which were respectively amended with 4% and 6% biochar. The dynamics of EC in V3 (4% biochar) was 1.48, 1.59, 1.76, 1.97, 2.24 and 2.43 dS/m while it was 1.56, 1.59, 1.64, 1.76, 1.82 and 2.1 dS/m in V1 without biochar amendment. The increase of EC could be attributed to the release of various ionic forms of potassium and phosphorus in addition to the release of NH_4^+ ions (Paul et al., 2020). The TKN was higher in V3 (2.15%) followed by V2 (1.8%), and V4 (1.71%) (Table 2). Similarly, the contents of TP (1.42%) and TK (1.74%) were higher in the vermicompost recovered from the treatment which received 4% biochar.

The addition of biochar at 4% was highly beneficial in increasing the quality of mixed leaf litter vermicompost. The enhancement of nutrients depends on various factors such as the nature of organic substrates, earthworm species used and type of amendments made. The addition of green manures to the vermicomposting substrates greatly improves the nutrient contents especially TKN, TP and TK while the addition of biochar enriches nutrients besides immobilizing heavy metals (Karmegam et al., 2019; Paul et al., 2020). The studies have shown that the biochar amendment up to 10% for improving the process as well as the quality of vermicomposting and vermicompost. The biochar amendment to green waste at a 6% level improved the quality of vermicompost (Gong et al., 2018). Sewage sludge-derived biochar (8%) addition to combined composting and vermicomposting of sewage sludge and wood chip mixtures was found to be an efficient system for waste conversion (Malińska et al., 2017).

Table 2. Physicochemical characteristics of initial and the final vermicomposting (50 days) substrates in different treatments. Values are mean ± standard error.

Treatments	Initial	Final (vermicompost)	Initial	Final (vermicompost)
pH			**TKN (%)**	
V1	7.45 ± 0.19	7.15 ± 0.18	1.05 ± 0.10	1.69 ± 0.16
V2	7.42 ± 0.16	7.32 ± 0.16	1.11 ± 0.10	1.8 ± 0.17
V3	7.61 ± 0.24	7.22 ± 0.22	1.15 ± 0.14	2.15 ± 0.26
V4	7.33 ± 0.20	7.26 ± 0.20	1.2 ± 0.15	1.71 ± 0.22
V5	7.56 ± 0.26	7.47 ± 0.25	1.13 ± 0.15	1.58 ± 0.21
EC (dS/m)			**TP (%)**	
V1	1.56 ± 0.15	2.1 ± 0.20	0.84 ± 0.08	1.13 ± 0.11
V2	1.51 ± 0.14	2.18 ± 0.20	0.82 ± 0.08	1.24 ± 0.11
V3	1.48 ± 0.18	2.43 ± 0.29	0.85 ± 0.10	1.42 ± 0.17
V4	1.42 ± 0.18	2.39 ± 0.30	0.89 ± 0.11	1.16 ± 0.15
V5	1.45 ± 0.19	2.24 ± 0.30	0.83 ± 0.11	1.11 ± 0.15
TOC (%)			**TK (%)**	
V1	42.87 ± 1.93	29.06 ± 1.31	1.1 ± 0.10	1.65 ± 0.16
V2	43.12 ± 2.24	30.42 ± 1.58	0.99 ± 0.09	1.39 ± 0.13
V3	45.91 ± 2.34	32.71 ± 1.67	1.13 ± 0.14	1.74 ± 0.21
V4	46.1 ± 2.17	34.45 ± 1.62	1.2 ± 0.15	1.31 ± 0.17
V5	48.23 ± 2.60	38.05 ± 2.05	0.99 ± 0.13	1.27 ± 0.17

Table 3. C/N ratio and C/P ratio of initial substrates and the final vermicompost (50 days) in different treatments. Values are mean ± standard error.

Treatments	Initial	Final (Vermicompost)
	C/N ratio	
V1	40.83 ± 3.88	17.20 ± 1.63
V2	38.85 ± 3.57	16.90 ± 1.55
V3	39.92 ± 4.83	15.21 ± 1.84
V4	38.42 ± 4.88	20.15 ± 2.56
V5	42.68 ± 5.72	24.08 ± 3.23
	C/P ratio	
V1	51.04 ± 4.85	25.72 ± 2.44
V2	52.59 ± 4.84	24.53 ± 2.26
V3	54.01 ± 6.54	23.04 ± 2.79
V4	51.80 ± 6.58	29.70 ± 3.77
V5	58.11 ± 7.79	34.28 ± 4.59

The TOC in the vermicompost of all the treatments decreased from initial levels. The TOC in vermicompost of V1 (no biochar) was lower than that of the treatments amended with biochar (T2-T5). The TOC dynamics in V1 was in the order of 42.87, 40.21, 38.67, 34.15, 30.33, and 29.06% respectively on 0, 10, 20, 30, 40 and 50 days. The final TOC content in other treatments was higher in the order of T5>T4>T3>T2. This is attributed to the addition of biochar at different levels. The reduction of TOC during organic matter decomposition elevated the level of nutrients in the final vermicompost. In addition, biochar incorporation played a major role in enhancing the nutrient contents. The C/N ratio is an important parameter to assess the maturity of the final composts and the C/N ratio below 20:1 is considered mature and agronomically useful (Karmegam et al., 2021). In the present study, the C/N ratio in vermicomposts of V1, V2, V3, V4 and V5 was 17.20 ± 1.63, 16.90 ± 1.55, 15.21 ± 1.84, 20.15 ± 2.56 and 24.08 ± 3.23, respectively in which T3 had a lower C/N ratio than the other treatments. The treatments V1, V2 and V3 had the final C/N ratio below 20:1 while T4 had 20.15:1 indicating that the C/N ratio of vermicomposts is falling in line with the organic compost standards. A lower C/P ratio of 23.04 was recorded in V3 with 4% biochar amendment (Table 3). The reduction of TOC and relative enrichment of nutrients during mineralization of organic materials is responsible for the reduction of the C/N ratio and C/P ratio (Paul et al., 2020; Rini et al., 2020). Based on the findings of the present study, the use of 4% biochar in vermicomposting of mixed leaf litter + cow dung (1:1) was beneficial in improving the nutrient quality (TKN, TP and TK) and in optimizing the C/N ratio.

Conclusions

Vermicomposting of mixed leaf litter + cow dung (1:1) employing *Eudrilus eugeniae* revealed that the biochar addition enhanced the vermicomposting and improved the nutrient quality of the vermicompost. The treatment, V3 with 4% biochar showed higher nutrient contents (TKN: 2.15%; TP: 1.42%; TK: 1.74%) with the least C/N ratio (15.21) when compared with the other treatments. The study results reveal that the use of 4% biochar in mixed leaf litter vermicomposting is highly beneficial and can be used for the production of enriched vermicompost.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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