Vermicomposting of harvested waste biomass of potato crop employing Eisenia fetida: Changes in nutrients profile and assessment of maturity of the end products

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Abstract

Vermicomposting potential of waste biomass of potato crop that are generated at the time of harvesting was studied employing Eisenia fetida. The experiment was carried out in pots taking two treatments; in one only potato plant biomass (PPB) was taken as raw materials whereas in the other a mixture of PPB with cow dung was engaged in the proportion of 5:1. The vermicomposted materials showed a reduction in C/N ratio, humification index, enhancement in nutrients profiles, ash contents, nitrogen-fixing, phosphate and potassium solubilizing bacterial population. The macronutrient enhancement in the vermicompost samples was recorded 3.8-4.4 fold for total N, 5-5.6 fold in available P, 1.6 fold in total K, 5.2-6.2 fold in total Ca and 1.6 fold in total Mg contents. The reduction in C/N was found in the rage of 92.5-94.4% in the vermicompost samples. The scanning electron microscope (SEM) images showed higher disintegration in the vermicompost products when compared with initial raw material and compost samples. Addition of cow dung significantly enhanced the quality and quantity of vermicompost final products besides positively affecting the earthworm population and biomass by the end of 60 days of experimental trials.

1. Introduction

Potato (*Solanum tuberosum*) which belongs to the Solanaceae family, is an important crop cultivated in several countries around the globe. It is the world's fourth most important food crop cultivated approximately in 19 million hectares of farmland and annual production of the crop has been recorded more than 378 million tons globally (Devaux et al. 2020). India is the second largest producer of potato (Scott et al. 2019; Rana and Anwer 2018) where approximately 1500 hectare per three lakh km^2 of land is used for its cultivation. It is the tuber or underground part of the crop which is used for direct consumption or other industrial uses. The above ground shoot/stem portions along with leaves that contribute towards the growth of underground tubers stop to grow at maturity and die. These above ground shoot/stem portions or biomass are not consumed by herbivores as it becomes dry or non palatable at the time of harvesting. According to an estimate, approximately 887.3 metric tons of dry waste biomass is generated in India per year after harvesting of potato tubers (Bisht and Thakur 2019). These huge volumes of waste biomass are either thrown away to the dumping ground, sometimes brunt, or even left in the field for decomposition. Such unscientific methods of waste management contribute significantly towards environmental degradation besides causing loss of nutrients. Burning of any biomass releases carbon dioxide and carbon mono-oxide to the environment and causes health hazards and pollution (Cheng et al. 2014). It has been reported that the waste dumping sites are one of the largest sources of global anthropogenic methane emissions (Powell et al. 2015) and unmanaged dumping/landfilling of post-harvest biomass is responsible for emission of 2.8 metric tons CH_4 /year or approximately 60 metric tons CO_2-eq per year (Cardoen et al. 2015).

As above ground biomass of potato crop has no other use at the time of harvesting (Cardoen et al. 2015); therefore, vermicomposting could be the better option for biomanagement of these wastes. Vermicomposting is considered as superior method among all other composting techniques as it is cost

effective, eco-friendly and very effective for sanitization of solid waste more particularly against the waste of biological origin (Lim et al. 2016; Sahariah et al. 2019). It is a bio-oxidative process in which earthworms and microbes along with other degradable community interact and accelerate the decomposition process of organic waste (Patwa et al. 2020). The vermicompost, end product of vermicomposting process has been reported for several beneficial effects in soil such as improvement in physical, chemical and biological conditions and can be used effectively to achieve sustainable agricultural growth (Das et al. 2019). Besides, vermicompost also enhances health related secondary metabolites in plants (Das et al. 2018). Application of vermicompost along with other organic amendments significantly improves the radical scavenging and antibacterial activity of plant's leaf (Das et al. 2016). The environmental impact such as greenhouse gas emission like methane is significantly lower and negligible during vermicomposting as compare to traditional composting (Nigussie et al. 2016). The efficacy of vermicomposting for management of different types of bio-waste including post-harvest biomass of agricultural field has already been established by several workers round the globe. For example, efficacy of vermicomposting has been tested in wheat crop residues (Suthar 2009), rice husk (Lima et al. 2012), citronella bagasse (Boruah et al. 2019), paper industry sludge (Karmegam et al. 2019) and others. However, the success of vermicomposting depends on several factors such as nature, origin, palatability, nutrients profile of substrate materials, type of earthworms and other environmental parameters that mainly include temperature and moisture. It has been reported that quality and quantity of vermicompost output entirely depends on the types of waste/substrate materials and the earthworm species used for the process (Deka et al. 2011a,b). Nevertheless, the reports on the vermicomposting potential of waste biomass of potato crop field that is generated at the time of harvesting are found to be very scanty. Therefore, an understanding of their use in waste conversion technologies is necessary to provide new insights on sustainable utilization and effective management of waste.

The earthworm *Eisenia fetida* is an epigeic species and their vermicomposting potential is well documented in the literature (Boruah et al. 2019). The small size, short life span, high reproductive rate and wide adaptability of *Eisenia fetida* makes them highly suitable for use in vermicomposting systems (Saba et al. 2019). Vermicomposting abilities of *Eisenia fetida* has been studied in wastes of different biological origin such as fruit and vegetable processing waste (Sharma and Garg 2017), cowdung and waste paper mixture (Unuofin and Mnkeni 2014), mixture of wheat straw, horse and sheep manure (Biabani et al. 2018) and others. However, studies about vermicomposting potential of *Eisenia fetida* on harvested waste biomass of potato crop are limited.

Considering the above mentioned facts, the present investigation was taken to study the vermicomposting potential of *Eisenia fetida* for conversion of waste biomass of potato crops into a value-added product. The efficacy of the overall vermicomposting process was judged based on changes in physicochemical, nutrients and microbial profiles, earthworm population and biomass, stability parameters such as ash contents, C/N ratio, humification index and scanning electron microscope (SEM) imaging of the end products.

2. Materials And Methods

2.1. Collection of potato plant biomass (PPB), cowdung (CD) and *Eisenia fetida*

The potato plant biomass (PPB) and fresh cowdung (CD) was collected locally from nearby harvested crop field and livestock farm of Gauhati University, Guwahati, Assam, India. For use in the experiment, the PPB was shade dried and cut into small pieces of 5 cm size. The individuals of *Eisenia fetida* were procured from Krishi Vigyan Kendra, Guwahati, Assam, India and their stock culture was maintained in the laboratory (Boruah et al. 2019).

2.2. Experimental design

The experiment was carried out in pots of 2L capacity (diameter 17cm and depth 18.5 cm) in laboratory conditions. A bed (3cm thick) for earthworm was prepared at the bottom of each pot by putting a small layer of sand and CD over the small bricks and stones. The vermicomposting experiment was conducted with two treatments maintaining three replicas for each. In one treatment PPB was taken as substrate material and in the other PPB and CD mixture was engaged in a ratio of 5:1 (Deka et al 2011a) in order to ensure the minimum use of CD with PPB. Previous authors have suggested about the use of CD with biowaste because it serves as the initial nutrients for earthworms, helps in microbial proliferation and enzyme activities during vermicomposting (Yuvaraj et al. 2021). In both the treatments equal amount of raw materials (100 g on a dry weight basis) was taken and kept for 10 days of pre-decomposition in order to avoid the adverse affects of heat released during early phase of decomposition and to create a conducive environment for earthworms activity (Karmegam et al. 2021) in the substrate mixture. Then, 30 individuals of *Eisenia fetida* were introduced to the substrate mixture from the stock culture. A similar control setup without earthworms was maintained for comparison of the results. The moisture levels in the pots were maintained at 60-65% by periodic sprinkling of water and the average temperature was 30±2°C during the 60 days of experimental trials. The vermicompost outputs as obtained from each treatment were calculated out on a dry weight basis whereas the earthworm population was counted manually and biomass was measured on fresh weight basis.

2.3. Physico-chemicals, biological and nutrient analysis

The samples of vermicompost, compost and raw materials were dried and analyzed in triplicate. The raw material (i.e. PPB and PPB+CD mixture) samples although analyzed separately but results were averaged and presented together. The pH and electrical conductivity (EC) were measured in 1:5 (w/v) water suspension using digital pH (Biochem PM79) and conductivity meter (Systronics 304) respectively. The ash content was estimated following Nelson and Sommers (1982) method. Walkey and Black titration method as outlined by Jackson (1975) was employed for the estimation of total organic carbon (TOC). Total Kjeldhal nitrogen (TKN) was determined by the micro Kjeldhal method (Jackson 1975). The C/N values were obtained from total organic carbon and nitrogen content of the samples. The available phosphorus (AP) was determined spectrophotometrically (Shimadzu UV 1601) following the stannous chloride method (APHA 1998). The total potassium (TK) and sodium (T Na) were determined in flame

photometer following acid digestion method (APHA 1998). The humification index was determined by employing the method as outlined by Boruah et al., (2019). The Ca, Mg, Zn, Fe, Cu, Mn, Cd, Ni, Co and Cr contents were analyzed by Atomic Absorption Spectrophotometer (Shimadzu AA 7000) after acid digestion of the samples. The total population of nitrogen-fixing, phosphorus and potassium solubilizing bacteria was estimated by the pour plate and serial dilution technique (Dubey and Maheshwari 2005; Boruah et al. 2019) and the results have been expressed as number of colony forming unit per gram (CFU g^{-1}). For enumeration of nitrogen fixing bacterial population Jensen agar media was used. On the other hand, Pikovskya agar and Aleksandrow agar media were used respectively for estimation of phosphorus and potassium solubilizing bacterial population.

2.4. Scanning Electron Microscopy (SEM)

The samples of vermicompost, compost and raw materials were oven dried at 70±2°C and powdered for SEM analysis. The analysis was performed by putting the samples uniformly over the metallic sample holder aided with a double-sided adhesive carbon tape and then coated with gold using a sputter coater (Bhat et al. 2015). Surface morphology of the samples was recorded at different magnifications and micrographs were obtained (Gemini, Sigma-300 series).

2.5. Statistical Analysis

SPSS (version 18) was used for statistical analysis of data. Vermicompost production of the two treatments were compared by independent sample *t*-test (two-tailed, $P<0.05$). Differences in physicochemical properties were compared by pair *t*-test. Results of earthworm productivity, microbial population and humification index were compared by ANOVA, LSD test ($P<0.01$).

3. Results And Discussion

3.1. Vermicompost production

The results of vermicompost production from PPB and PPB+CD mixture are presented graphically in Figure 1. The vermicompost production was recorded 47.33% from PPB and 54.11% from PPB+CD mixture indicating significant enhancement in the outputs after the addition of CD. This result agrees with the previous findings of Mohapatra et al. (2019) who have reported about 39-54% vermicompost production during vermicomposting of paper mill sludge. Several factors are associated with vermicompost production which includes types, initial population, reproductive and metabolic activities of the earthworms; physicochemical, nutrients composition and amount of resource materials and time duration of experimental periods (Sharma and Garg 2018). Besides, the addition of CD with PPB enhances the palatability of substrate (Negi and Suthar 2018) and gives a better environment for the fecundity of the earthworms (Xie et al. 2016) which ultimately helps in higher production of vermicompost.

3.2. Changes in physicochemical profiles (pH, EC, ash, TOC, and Na)

The results of physico-chemical analysis including pH, EC, ash, TOC and Na are presented in Table 1. There was a marginal decrease in the pH values towards the neutral range in both compost and vermicompost samples when compared with initial raw material. The pH values in the compost samples were found in the range of 6.73-7.11 whereas in vermicompost samples it was within 6.63-6.93. The variation in pH values among the different samples was not significant. Earthworms can neutralize the pH level in the end products (i.e. vermicompost). The decrease in the pH level in the vermicompost samples has been reported by earlier workers (Suthar et al. 2017). The decrease in pH values is associated with the mineralization of nitrogen and phosphorus, production of CO_2 and NH_3 during vermicomposting process due to humification process (Cao et al. 2016). Further, shifting of pH during vermicomposting is a dynamic process and dependent on the initial substrate materials used for bioconversion which can be attributed to the production of different intermediate species of organic acids in the process (Yuvaraj et al. 2018; Karmegam et al. 2019). The pH is an important parameter for determining the quality of compost/vermicompost and pH level near the neutral range indicates the stabilization of the vermicomposted products (Esmaeili et al. 2020; Perez-Godínez et al. 2017)

The EC contents have increased significantly in both vermicompost and compost samples as against the initial values of raw materials (Table 1). The increase in EC level was 1.3 fold in compost and 1.9 fold in vermicompost samples. The bioconversion of organically bound nutrients into available forms, the release of different soluble salts, ammonium and other inorganic ions/compounds enhance the EC values in the vermicomposted materials (Lukashe et al. 2019; Karwal and Kaushik 2020). Further, higher contents of EC in the vermicompost samples than the compost counterpart may be attributed to the differences in mineralization rate and accumulation of ions (Negi and Suthar 2018) which become more in presence of earthworms. Nevertheless, the EC levels were found within the permissible limits of organic product application and not beyond the safe limits of phytotoxicity (Li et al. 2012).

There was 71.2-75.6% loss in TOC contents in the vermicompost samples whereas it was 42.5-46.5% in case of compost/control. The TOC loss was found greater in the samples of PPB+CD treatment. The C mineralization, humification and decrease of mass in the substrate materials during composting and vermicomposting cause reduction in TOC in the final products (Negi and Suthar 2018). Besides, earthworms bring chemical modifications in the substrate materials and provide a favourable environment for the proliferation of microbes (Aira et al. 2007). This joint activity of earthworms and microbes brings higher consumption of organic carbon as their energy source (Devi and Khwairakpam 2020) and causes higher falls in TOC in the vermicomposting systems. Moreover, it has been suggested that earthworms efficiently consume the pre-decomposed waste materials and brings more organic matter decomposition which ultimately cause higher reduction in TOC in the vermicompost samples (Esmaeili et al. 2020). The present finding shows the conformity with earlier findings (Khaket et al. 2012) who have reported up to 63.73% reduction in TOC values in the vermicomposted samples. Besides, reduction in TOC in the range of 78.5-86% has been reported by Boruah et al. (2019) which can be attributed to the substrate condition that influences the microbial and worm's activities during vermicomposting process.

The compost samples recorded about 1.3 fold increase in ash value whereas in case of vermicompost samples it was 1.6 fold. Addition of CD with raw materials also results in a significant enhancement in ash level in the end products (Table 1). The present finding showed similarity with the previous works of Devi and Khwairakpam (2020) who observed the increasing ash contents in the vermicomposted samples of *Lantana camara.* The degradation of cellulose, hemicelluloses, lignin; release of CO_2 and mineralization of the waste materials during vermicomposting enhance the ash values in the final products (Chatterjee et al. 2016).

The Na contents have decreased significantly in the final products and are found in the range of 90.85-110.85 mg/kg and 50.5-60.52 mg/kg in the compost and vermicompost samples respectively. The decrease in Na content in the vermicompost samples has been reported by the previous worker (Mohapatra et al. 2019) which can be attributed to the absorption of Na by earthworms, besides, the possibility of Na volatilization due to activity of microbes and earthworms during vermicomposting cannot be ignored.

3.3. Changes in macronutrients composition (TKN, AP, TK, Ca and Mg)

The results of TKN, AP, TK, Ca and Mg contents are also presented in Table 1. The result showed 2 folds increase in TKN values in the compost samples. In vermicompost samples, TKN enhancement was found in the range of 3.8-4.4 folds by the end of the experimental trials. Moreover, there was a significant enhancement in TKN contents in vermicompost samples of PPB+CD than the PPB. The nitrogen enhancement in the final products was mainly governed by some gut-associated phenomena of earthworm's such as the release of hormones and enzymes during the vermicomposting process (Gomez-Brandon and Dominguez 2014). Besides, earthworm’s body fluid, mucus, excretory products and decaying tissues of dead earthworms also determined the nitrogen level in the vermicomposted products (Bhat et al. 2015). This results agreed the previous findings where it was reported that enhancement in TKN contents may vary depending on the substrate/raw materials and or other organic amendments used for vermicomposting (Sudkolai and Nourbakash 2017; Karmegam et al. 2019). Increase in AP was recorded 3.9-4.4 folds in compost and 5.0- 5.6 fold in vermicompost samples than the initial substrate materials. Addition of CD with the PPB significantly enhanced the AP level in both compost and vermicompost samples. It has been suggested that joint action of earthworms and microbes were responsible for the enhancement of AP in the vermicomposted products and these activities became accelerated in presence of cow dung (Deka et al. 2011a,b). Besides, higher level of AP in the vermicompost samples could attribute to the activities of phosphate solubilizing bacteria (Mupambwa et al. 2015) and release of faecal phosphatase enzyme by earthworm's gut microbes (Singh and Kalamdhad 2016). The concentration of TK had increased up to 1.6 fold in the vermicompost samples but marginally decreased in the compost than the initial value of the raw materials. The physical breakdown of substrate materials and release of endogenic and/or exogenic enzymes due to activity of earthworms and microbes causes rise in total K in the vermicomposted samples (Bhattacharya et al. 2016). Further, the decrease in TK values in the compost/control sample may be attributed to the poor mineralization of the substrates besides some microbes might utilize the already available potassium for their metabolism. The increase

in total Ca was recorded 2.5 fold in compost whereas it was 5.2-6.2 folds in vermicompost samples as against the initial values found in raw materials. Similarly, there was a single fold increase in total Mg in compost samples as against 1.5 fold in the vermicompost materials. The variations Ca and Mg contents observed in the raw material, compost and vermicompost samples were statistically significant. These findings can be corroborated with the previous works of Malinska et al. (2016) who has reported that waste mineralization process during vermicomposting releases the Ca and Mg from bind to free form and enhanced their level in the end products.

3.4. Changes in C/N values

The C/N values have declined sharply in both compost and vermicompost samples when compared with raw materials (Figure 2). The decline in C/N values was 72.5-73.8% in compost and 92.5-94.4% in case of vermicompost samples. The enhanced level of nitrogen and organic matter decomposition during the vermicomposting helps in higher reduction of C/N values in the end products (Singh and Kumar 2017). The results are in accordance with the previous findings of Ananthavalli et al. (2019) where 38.64% reduction in C/N values was reported in the vermicompost samples against the traditional compost. The C/N ratio is an important parameter for microbial activity and the worm's fecundity during vermicomposting and a key parameter for compost maturity (Yadav and Garg 2016). The C/N value below 20 indicates the stabilization of vermicomposted materials (Perez-Godínez et al. 2017) whereas a value less than 15 confirms their suitability for agronomic use (Bourah et al. 2019).

3.5. Humification Index (HIX)

The results of HIX are presented in Figure 3. The average value of humification index in the initial substrate materials was 6.24±0.78 and it was 2.44±0.21 and 2.66±0.3 respectively in the compost samples of PPB and PPB+CD. On the other hand, the HIX values were found to be 1.94±0.4 and 1.61±0.2 in the vermicompost samples of PPB and PPB+CD mixture respectively. Humification index is an indicative parameter for compost/vermicompost stabilization. The joint action of microbes and earthworms are probably responsible for decomposition and stabilization of waste materials and this process become more accelerated in the presence of CD resulting in greater reduction HIX in PPB+CD treatment. The HIX below 5 is indicative of a high level of humification of organic matter in waste material (Ravindran et al. 2013).

3.6. Scanning Electron Microscopic (SEM) evaluation

The SEM analysis provides an important insight on changes in surface morphology of the raw materials during vermicomposting. The SEM analysis has been frequently used by researchers to determine the maturity of the composting/vermicomposting end products (Balachandar et al. 2021). The snapshots of SEM analysis showed the compact, robust and folk like appearance of the initial substrate/raw materials. On the other hand, there were significant changes in physical appearance in the vermicompost samples ensuring scattered, smaller and disintegrated structure. A similar pattern of physical appearance showing less disintegration was also evident in the compost sample. Lim and Wu

(2015) suggested that ingestion of waste materials through earthworm gut resulted in the fine texture/structure of the end products which may give scattered and smaller surface appearance in SEM micrograph. It has also been suggested that earthworms and its gut-associated microbes secret several enzymes to accelerate the biodegradation of substrate materials and brings changes in morphological structure indicating higher maturity of the vermicomposting end products (Srivastava et al. 2020; Balachandar et al. 2021).

3.7. Trace elements and heavy metals

The results of trace element and heavy metals as revealed in Table 2 showed enhancement in the concentrations of Zn, Fe, Mn, Ni and Cr in both compost and vermicompost samples. The increase was in the range of 1.3-2.6 folds in the vermicompost and 1.05-1.3 folds in the compost samples. Similarly, there was a significant decrease in the Cu, Cd and Co concentration in vermicompost samples than the initial level of raw materials. The decrease was found in the range of 0.8-2.1 folds in the vermicompost samples whereas in case of compost samples no significant changes have been observed. Earlier workers have established that trace elements and heavy metals profile in the vermicomposting products can be diverse (Song et al. 2014) and accordingly both increase/decrease in metal and trace elemental level is possible. It has been suggested that composting and vermicomposting enhanced the trace elemental concentrations due to loss of weight and volume in organic matter resulted from decomposition, the release of carbon dioxide and mineralization processes which usually go faster in presence of earthworms (Malinska et al. 2016). On the other hand, a decrease in metals and trace elements concentration is due to the bioaccumulation of these elements in earthworm’s tissue (Panday et al. 2014). It has been suggested that earthworms releases metallothionein isoform in the intestine and binds the excess metal ions by forming organo-metallic ligands which ultimately inhibits the release of metals during vermiconversion process (Maity et al. 2009; Goswami et al. 2013). Nonetheless, metal concentrations in the vermicompost samples were found within the range of international as well as Indian permissible levels for compost applications in agriculture and horticulture (Mohee and Soobhany 2014; Mandal et al. 2014).

3.8. Beneficial bacterial population

There was a significant enhancement in the population of nitrogen-fixing, phosphate and potassium solubilizing bacteria in vermicompost samples when compared with the compost and initial substrate materials (Table 3). Higher increase was found in the vermicompost and compost samples of PPB+CD mixture. The enhancement in beneficial microbes in the earthworm processed substrates has been reported heavily by previous researchers (Ravindran et al. 2015). The release of nutrients in earthworm's gut from the ingested materials perhaps provide a conducive environment for the proliferation of bacterial community which ultimately enhance the beneficial bacterial populations in the earthworms excreta or vermicompost. Further, an increase in the beneficial bacterial population in vermicompost indicates enhanced stabilization of macro and micronutrients which primarily depends on the type and combination of original substrate materials (Boruah et al. 2019).

3.9. Earthworm population and biomass

The results as revealed in Table 4 showed 1.3 and 1.7 folds increase in earthworm number and biomass in the PPB treatment. The addition of cowdung significantly enhances the earthworm numbers and biomass and thus PPB+CD treatment recorded a 1.6 fold increase in earthworm numbers and 3.7 fold increase in biomass values over the initial level. The present findings are in agreement with the previous workers (Dominguez et al. 2019). The increase in worm population and biomass is linked with survival, growth rate and reproductive potential of the earthworms which again governed by the palatability and quality of the resource materials used in the vermicomposting process (Sharma and Garg 2019). It has been suggested that the substrate materials that contain sufficient amount of metabolizable organic matter favor the earthworm's growth (Edwards 1988) which justify the enhanced population as well as biomass in the CD added treatment. Besides, several studies have suggested that an increase in earthworm weight/biomass is associated with the microbial population as earthworms take microbes as additional food (Bhat et al. 2015).

4. Conclusion

Vermicomposting of harvested waste biomass of potato crop is feasible by employing *Eisenia fetida.* The vermicomposting end products were enrich with plant's available macro and micro nutrients and found superior than traditional compost. The concentration of toxic metals such as Cr was found within permissible limits in the vermicompost samples. The neutral pH and C/N ratio confirms the use of the vermicompost as a horticultural growing medium. The study brings into light about the effective use vermitechnology for management potato plant biomass and also boosts up the marketability of the end products.

Declarations

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Tables

Table1: Showing physico-chemical and macronutrient profiles of raw material, compost and vermicompost samples

Parameters	Raw Materials[aa]	C1	C2	VC1	VC2
pH	7.73±0.15a	7.11±0.01b	6.73±0.25c	6.63±0.27c	6.93±0.21d
Conductivity (mS/cm)	1.7±0.08a	2.24±0.20b	2.17±0.17b	3.06±0.15d	3.25±0.21d
Organic Carbon (g/kg)	545.4±2.1a	313.6±1.2b	292±1.7c	156.9±4.0d	132.7±2.7e
Ash Content (g/kg)	540.3±2.7a	694±10.4b	759.6±10.7c	853±6.3d	892±8.6e
Na (mg/kg)	140.5±1.1a	90.9±1.5b	110.9±1.3c	50.5±1.3d	60.4±1.1e
Total Kjeldhal N (g/kg)	4.12±0.67a	8.61±1.56b	8.43±1.1b	15.7±1.3c	18.2±0.92d
Available P (mg/kg)	1483.2±11.5a	5839.4±9.8b	6638.4±8.67c	7421.9±9.2d	8402.4±7.2e
Total K (mg/kg)	175±5.3a	173.57±5.5a	172±5.72b	261.67±4.57d	278.9±6.8c
Total Ca (mg/kg)	1.32±0.21a	3.12±0.56b	3.34±0.47b	6.9±1.31c	8.27±1.3d
Total Mg (mg/kg)	668±5.3a	694.7±7.5b	699.2±6.1b	987.2±3.4c	998.6±3.2c

Mean Value ±SD, n=3, Different letters in the same row indicates significant variations; (Pair *t*-test P <0.05, two tails).
aa = Represent the average values of two substrate materials
C1 = Compost samples of PPB
C2 = Compost samples of PPB+CD (5:1)
VC1=Vermicompost samples of PPB
VC2= Vermicompost samples of PPB+CD (5:1)

Table 2: Showing the trace elements and heavy metals concentrations in raw material, compost and vermicompost samples

	Treatments			
Heavy Metals (mg/kg)	Raw Materials[aa]	Compost[cc]	VC1	VC2
Zn	16.2±1.4a	17.1±1.7b	23.3±1.6c	28.7±1.1d
Fe	148.7±2.6a	163.9±3.2b	224.6±4.3c	259.2±3.3d
Cu	6.5±0.6a	6.17±0.35a	5.72±0.81b	5.49±0.65b
Mn	12.7±1.21a	15.43±1.4b	28.44±1.8c	34.21±2.3d
Ni	1.4±0.2a	1.7±0.23a	2.3±0.3b	2.9±0.4c
Cd	0.7±0.06a	0.529±0.05b	0.43±0.07c	0.32±0.02d
Co	1.5±0.43a	1.4±0.64a	0.8±0.12b	0.7±0.12b
Cr	0.4±0.05a	0.43±0.03a	0.52±0.21b	0.58±0.37c

Mean Value ±SD, n=3, Different letters in the same row indicates significant variations; (Pair *t* test $P < 0.05$, two tails).
aa = Represent the average values of two substrate materials
cc= Average values of two compost samples obtained from potato plant biomass and potato plant biomass plus cowdung mixture
VC1=Vermicompost samples of PPB
VC2= Vermicompost samples of PPB+CD mixture (5:1)

Table 3: Showing the beneficial bacterial population in raw material, compost and vermicompost samples

Treatments	N fixing (CFU g^{-1})	P solubilising (CFU g^{-1})	K solubilising (CFU g^{-1})
Raw Materials[aa]	7.66×10^6±2.0a	29.66×10^6±1.37a	9.33×10^6±1.5a
C1	10.3×10^6±1.7a	39.33×10^6±1.92a	10.33×10^6±1.02b
C2	16×10^6±2.6a	62×10^6±1.68a	10×10^6±1.58b
VC1	48.33×10^6±2.1a	108.33×10^6±2.3b	13×10^6±0.5c
VC2	52.66×10^6±1.97a	106.33×10^6±1.93a	23.33×10^6±1.9b

Mean Value ±SD, n=3, Different letters in the same row indicates significant variations; (Pair *t*-test $P < 0.05$, two tails).
aa = Represent the average values of two substrate materials

C1 = Compost samples of PPB
C2 = Compost samples of PPB+CD (5:1)
VC1=Vermicompost samples of PPB
VC2= Vermicompost samples of PPB+CD (5:1)

Table 4: Showing changes in population and biomass values of *Eisenia fetida* during vermicomposting of two different treatments

Treatments	Population		Live Biomass (g)		% Change in Biomass
	Initial	Final	Initial	Final	
PPB	30	37.8±2.1a	0.142±0.02a	0.251±0.07b	76.8
PPB+CD	30	49.3±2.7c	0.149±0.09a	0.563±0.09d	277.8

Mean value±SD, n=3; Different letters indicates statistically different values (ANOVA, LSD test, $P < 0.01$).

Figures

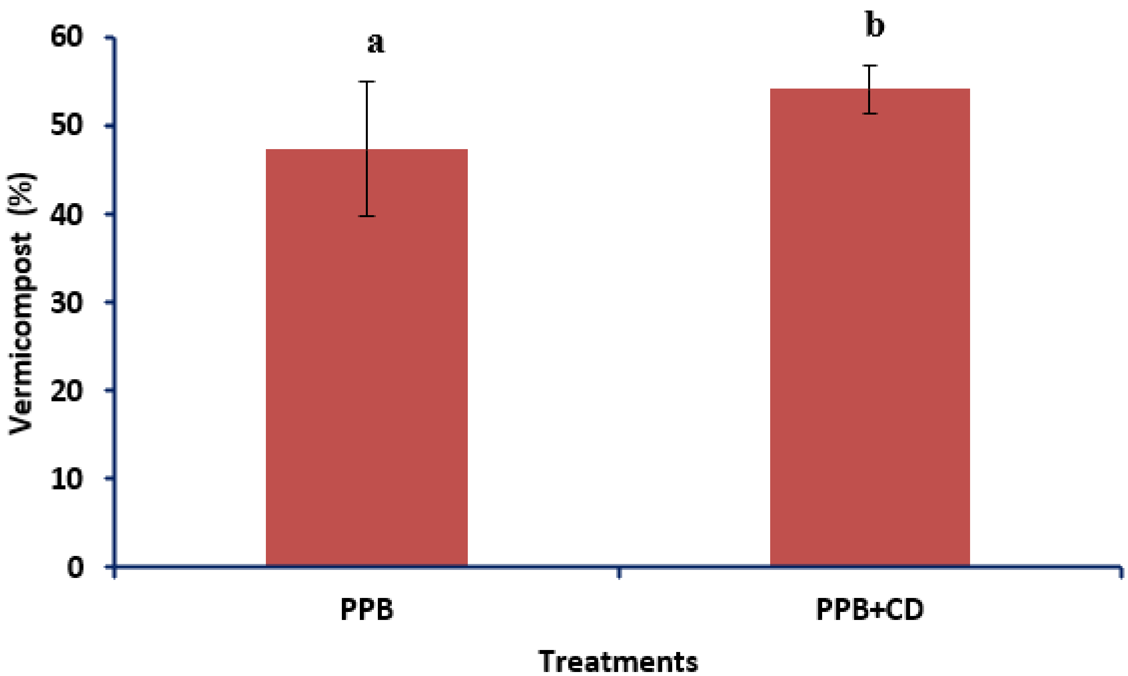

Figure 1

Showing the vermicompost production from PPB and PPB+CD mixture. Values are mean, n=3, bars indicate SD. Statistical differences are indicated by different letters ($P<0.05$, Pair t-test, two tails).

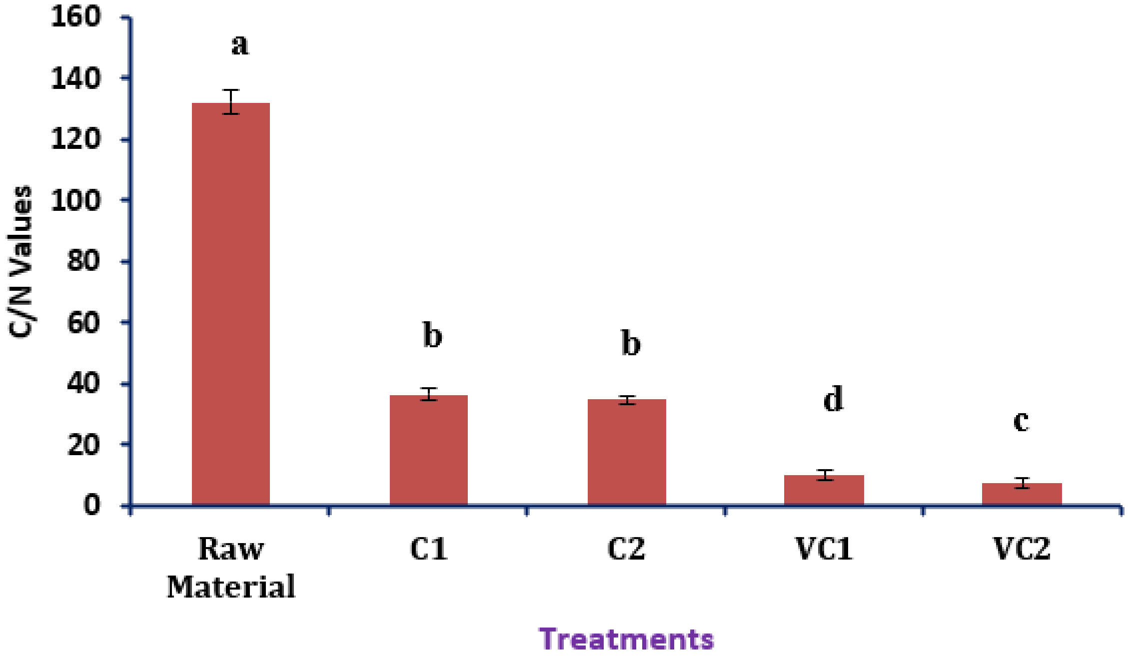

Figure 2

Showing the C/N values of the raw material, compost and vermicompost samples. Values are mean, n = 3, bars indicate SD. Significant differences indicated by different letters (P<0.05, Pair t-test, two tails). Raw material represents the average values of PPB and PPB+CD mixture C1 = Compost samples of PPB C2 = Compost samples of PPB+CD (5:1) VC1=Vermicompost samples of PPB VC2= Vermicompost samples of PPB+CD (5:1)

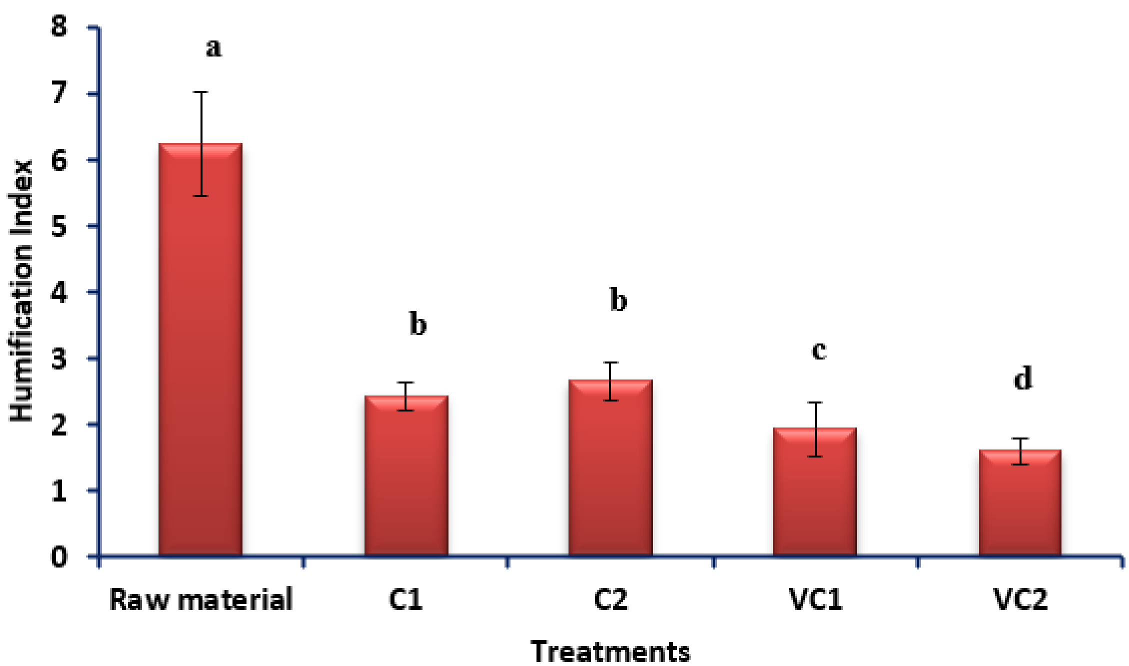

Figure 3

Showing humification index values of raw material, compost and vermicompost samples. Values are mean, n = 3, bars indicate SD. Significant differences indicated by different letters ($P<0.05$, Pair t-test, two tails). Raw material represents the average values of PPB and PPB+CD mixture C1 = Compost samples of PPB C2 = Compost samples of PPB+CD (5:1) VC1=Vermicompost samples of PPB VC2= Vermicompost samples of PPB+CD (5:1)

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