Recycling of Castor (Ricinus communis) Straw through Vermicomposting using Epigeic Earthworms (Eisenia fetida and Perionyx sansibaricus)

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Recycling of Castor (*Ricinus communis*) Straw through Vermicomposting using Epigeic Earthworms (*Eisenia fetida* and *Perionyx sansibaricus*)

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ABSTRACT

A large amount of castor straw production in arid and semi-arid environment warranted a need for its management through vermicomposting. Hence a comparative efficacy of the epigeic earthworm species *Eisenia fetida* and *Perionyx sansibaricus* in castor straw recycling was analyzed. The earthworm species *E. fetida* and *P. sansibaricus* were employed in bedding material containing a mixture of castor straw and cow dung in equal proportions (1:1 w/w). Vermicomposting was carried out for 90 days and changes in physicochemical parameters of beddings were observed at an interval of 15 days. The process of vermicomposting showed a significant increase in electrical conductivity (1.25 to 2.60 dsm^{-1}), total nitrogen (7.03 to 15.31 g kg^{-1}), available phosphorus (3.13 to 6.76 g kg^{-1}) and potassium (2.34 to 6.94 g kg^{-1}) but a decrease in pH (8.25 to 7.27), organic carbon (342 to 195 g kg^{-1}) and C/N ratio (48.62 to 12.75) in worm worked bedding substrates from 0 day to 90th day. The *E. fetida* performed better than *P. sansibaricus* in decomposition of agrowaste (castor straw) and production of nutrient rich vermifertilizer. The earthworm *E. fetida* and *P. sansibaricus* can be employed for stabilization of castor waste and production of vermifertilizer and in turn socioeconomic upliftment of farmers in rural areas.

Key words: Agrowaste, Physiochemical parameter, Recycling, Vermibed, Vermifertilizer

The castor crop is mainly cultivated in India, China and Brazil [1]. India has the largest area (11.48 lakh ha) and highest productivity (1666 kg ha^{-1}) in the world [2]. Castor straw is not easily degraded when left in the agriculture field. Usually, waste of castor crop such as leaves, branches and stems are burned to prepare the soil for the next harvest. However, castor waste may be used for making organic fertilizer through a vermicomposting process as well as measure to reduce pollution. Rosiane *et al*. [3] used castor meal blends with castor husk as an organic fertilizer to promote plant growth. The utilization of the raw material of crop in productive manner by vermitechnology leads to manufacture of biofertilizer. In vermiculture-biotechnology (VBT) the castor residue may be used as feeding material for vermifertilizer production. Earthworms are considered as ecosystem engineers they play an important role in molding soil structure and cycling nutrients [4]. They promote litter decomposition and mineralization through their feeding and burrowing activities and play a vital role in providing the ecosystem services [5]. Earthworms feed on soil and dead or decaying plant remains including straw, leaf litter and dead roots. They are the principal agents in mixing dead surface litter with soil, making the litter more accessible to decomposition by soil microorganisms. Cattle dung is also an attractive food for many earthworm species and their digestive system. Earthworms concentrate the organic and mineral constituents in the food they eat so their casts are nutrient rich than the surrounding materials. They improve the nutrient availability, drainage, texture and productivity of soil system. Vermicomposting has been developed as an eco-friendly technology in which earthworms interacts with microorganisms and allows the stabilization of organic matter and modify physiochemical and biological properties of bedding [6]. It plays a central role in mineralization, nutrient recovery and microbial activity leading to vermifertilizer production [7]. Epigeic earthworms are more suitable for vermicomposting because they live in organic horizons and feed primarily on decaying organic matter [8] and their cast has more stability than the endogeic earthworms [9]. *Eisenia fetida*, *Perionyx excavatus* and *Eudrilus eugeniae* epigeic earthworm species are mainly used in composting process in India [10]. Among these *Eisenia fetida* is the most common species employed in vermicomposting [11]. The use of earthworms in vermicomposting reduces the waste stabilization time and provides nutrient rich vermifertilizer [12]. They serve as a

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scavenger and help to decompose the dead and decayed organic materials and increase soil fertility [13].

Cellulose, hemicellulose and lignin are mainly reported from caster fibrous waste with few undesirable constituents such as ash and extractives by Vasconcelos et al. [14]. Among these, cellulose is found in the highest percentage. Earthworms reduce 40-60% waste volume and make nutrients availability to the plants with decrease in the C/N ratio and hazardous materials [15]. The recycling of organic wastes through vermicomposting has become important worldwide due to high fertilizer cost and minimum availability of organic manure [16]. Vermicomposting is an advance, inexpensive, and environmental friendly biotechnology that uses earthworms [17]. Bhat *et al*. [18] documented that earthworms serve as decomposer of organic waste and producer of biofertilizer. Boruah et al. [19] recorded reduction in C/N ratio and humification index but enhancement in nutrients profile, nitrogen fixing, phosphate and potassium solubilizing bacterial population in the vermicompost of citronella bagasse and paper mill sludge mixture accompanied by *Eisenia fetida*. The composting potential of *Perionyx sansibaricus* and *Eisenia fetida* has been investigated [20-22]. They observed a significant increase in total nitrogen, available phosphorus and potassium and decline in pH, carbon and C/N ratio of agrowaste. Biruntha *et al*. [23] conducted research on vermicomposting of seaweed, sugarcane trash, coir pith and vegetable waste with cow dung using *Eudrilus eugeniae* and found decline in pH an increase in electric conductivity (EC) during vermicomposting. The organic carbon, lignin, cellulose, C/N and C/P ratios in vermicompost were significantly lower than the compost, while NPK content of vermicompost increased significantly. Vermicomposting of sewage sludge by *Eisenia fetida* and its application in agriculture have been investigated [24]. They recorded decrease in number of fecal coli and organic matter content, and also an increase in EC and stabilization in pH of vermicompost.

Biofertilizer processing or vermicomposting is an efficient and sustainable technique that can help in maintaining the soil nutrients in agriculture ecosystem. This is an eco-friendly, cost-effective approach and best among other bioremediation techniques [25]. The use of such vermiculture biotechnology in the field at large scale can potentiate sustainable development by improving the economic, social and ecological condition [6]. Some studies have described the use of castor oil seed/castor bean waste [3], [26-28] but not of the castor straw for composting. Since a large quantity of castor waste mainly caster straw is generated from castor crop grown in Rajasthan [29], it warranted a need to convert castor straw into a nutrient rich vermicompost. Therefore, the castor straw was selected as feed material for two epigeic earthworm species (*Eisenia fetida*- exotic and *Perionyx sansibaricus*- native species) in vermicomposting, and the physico-chemical changes were compared during castor waste stabilization.

MATERIALS AND METHODS

Experimental design and sample collection

Castor straw was procured from the farmers of Sirohi district of Rajasthan and cattle dung was collected locally from livestock owners. The physiochemical parameters of raw materials at 0-day decomposition are given in the table. The earthworm species *Eisenia fetida* was obtained from the vermiculture unit in Kanhaiya Goashala, Pal Balaji Road, Jodhpur and *Perionyx sansibaricus* was collected from the study area. Both the species were reproductively mature having clitellum. Initially vermibed substrates were allowed to decompose partially before inoculation of earthworm. Partially decomposed castor straw mixed with cow dung was used to prepare the separate vermibeds for *E. fetida* and *P. sansibaricus.* The moisture level (65-80%) of bedding material was maintained by spraying of tap water. Vermibed temperature (27±3°C) was maintained by covering it with wet jute bags. Triplicate sets of vermibeds (each 3kg) were prepared by using castor straw: cow dung (1:1 w/w) in containers (30 cm diameter × 25 cm height) with holes in bottom for drainage of excess water. In each vermicomposting set 25 mature worms of each earthworm species were inoculated separately. Control beddings were kept for comparison. The experiment was conducted for 90 days along with control to evaluate the compositing potential of selected earthworm species. The samples of bedding materials were collected on the day 0, 15, 30, 45, 60, 75 and 90 of the experimentation.

Measurement of physiochemical parameters

pH, electric conductivity, temperature and moisture

Ten gram air dried sample was mixed with 100ml of distilled water. Suspension of 1/10 (w/v) dilution was shaken and left for 30 minutes. The pH and electric conductivity of suspension was estimated by using pH meter and electric conductivity meter respectively. The vermibed temperature was measured on alternate day by hand soil thermometer. Moisture content of the vermibed was estimated gravimetrically by oven drying of sample at 105°C.

Organic carbon

Organic carbon was measured by Walkley and Black [30] method. One gram of air-dried sample was treated with 10 ml of $K_2Cr_2O_7$ solution in 500 ml flask then shacked well. Thereafter, 20 ml con. H_2SO_4 was added and left for 30 minutes followed by addition of 200 ml of distilled water, 10 ml of phosphoric acid and 1 ml of diphenyl amine indicator. It was then titrated against ferrous ammonium sulphate solution. At the end point, the colour of the suspension changed from violet to bright green through blue.

Total nitrogen

The total nitrogen content was estimated by micro-Kjeldahl methods as described by Anderson and Ingram [31]. Fifty gram of air dried sample was taken in a micro-Kjeldahl distillation flask and 1 ml of borax buffer solution was added. Five milliliter of boric acid indicator was put and then the Kjeldahl flask was heated. Distillation was done for 10 minutes afterwards 40 ml of distillate was collected in a conical flask. Conical flask was removed when the distillation color turned to blue due to dissolution of ammonia. The distillate was titrated in conical flask against 0.01N HCl till faint pink or brown colour appeared.

Available phosphorus

The procedure adopted for estimation of available phosphorus was based on the method of Olsen's [32]. One gram of air-dried sample was taken to which 200 ml of sulphuric acid (0.002N) was added. The suspension was filtered and 25 ml of filtrate was taken to which 1 ml of ammonium molybdate and 3-4 drops of stannous chloride solution were added. A blue color appeared after 10 minutes. The absorbance was recorded at 690 nm by spectrophotometer. The values were calculated with the help of standard plot.

Potassium

Potassium was measured by the method of Simmard [33] using a flame photometer. The air pressure was kept at 5 lbs and the gas feeder was adjusted to have a blue sharp flame. Soil extract was used as sample and readings were taken at 769 nm. The standard potassium solution was feed and the flame photometer was adjusted to read full value of emission. Zero value of the meter was adjusted by feeding distilled water. The values were calculated with the help of standard plot. At the end point the dull green color changed to the bright green.

The C/N ratio was calculated by the values of carbon by nitrogen. One-way analysis of variance (ANOVA) of the data was performed with the help of SPSS package.

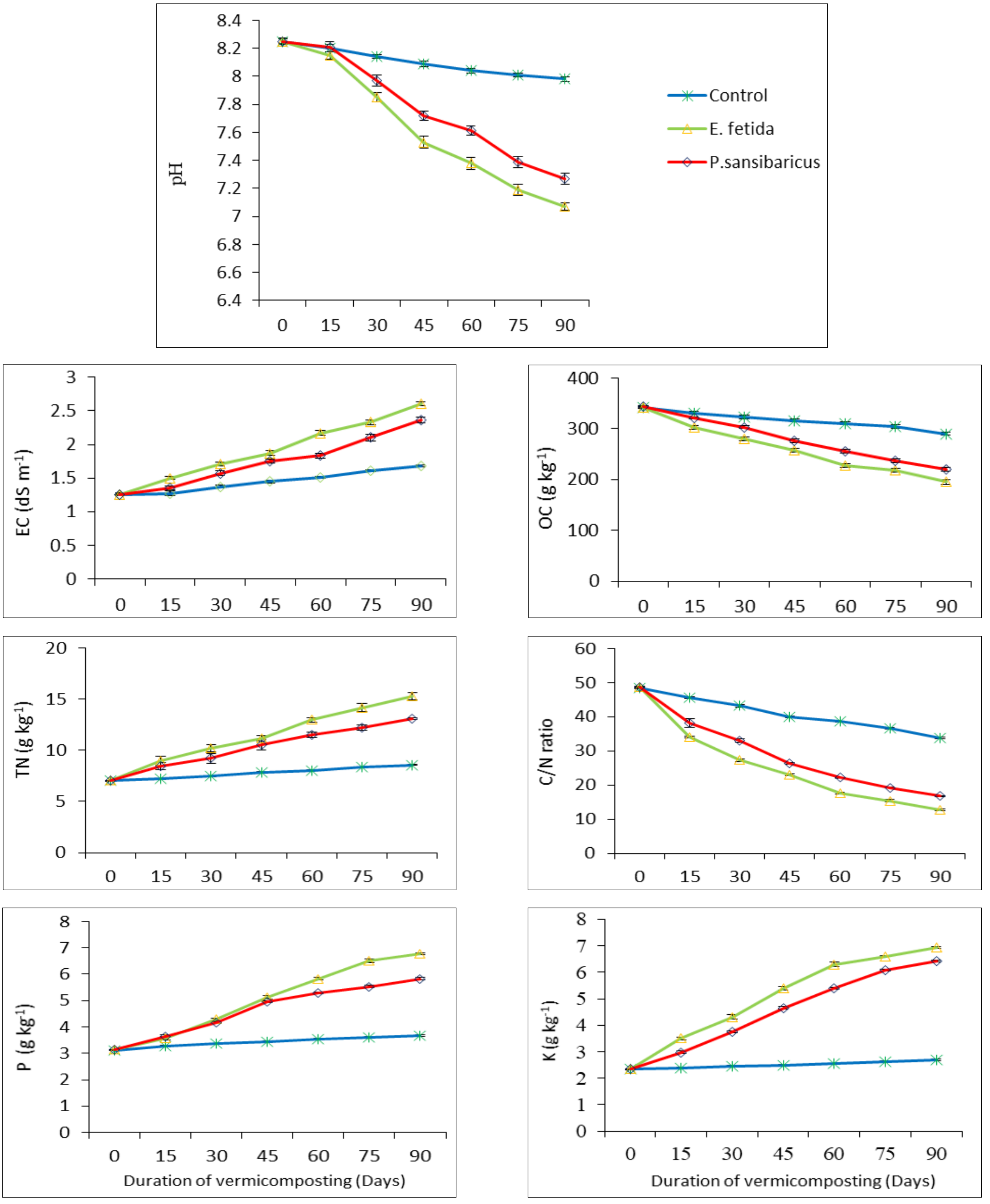

Fig 1 Effects of earthworms (*Eisenia fetida, Perionyx sansibaricus*) on pH, electric conductivity (EC), organic carbon (OC), total nitrogen (TN), phosphorus (P) and potassium (K) in caster straw plus cow dung bedding material

RESULTS AND DISCUSSION

Earthworm amended castor straw plus cow dung bedding showed significant variation (P<0.001) in its physiochemical properties with respect to changes in decomposition period. In control bedding, the values of pH, organic carbon and C/N ratio decreased, while the electrical conductivity, total nitrogen, phosphorus and potassium increased significantly. In control bedding total nitrogen content increased by 1.15-fold. In contrast, organic carbon and C/N ratio declined by 14.94% and 26.04% respectively. *Eisenia fetida* inoculated bedding materials showed significant variation (P<0.001) in the value of pH, organic carbon, C/N ratio, electrical conductivity, total nitrogen, phosphorus and potassium. The pH declined by 11.87%. Likewise, organic carbon and C/N ratio reduced by 42.88% and 73.77% respectively. In the same way, experimental bedding indicated 2.06, 2.17, 2.15 and 2.96 fold increases in electrical conductivity, total nitrogen, phosphorus and potassium respectively after 90 days as compared to initial values (Fig 1). Physiochemical properties of the bedding materials with *Perionyx sansibaricus* changed significantly (P<0.001) during 90 days. The vermibeds showed a gradual enrichment in electrical conductivity, total nitrogen, phosphorus and potassium. However, the value of pH, organic carbon and C/N ratio reduced gradually from 0 to 90 days. Declines in values of pH, organic carbon and C/N ratio were 10.30%, 36.11% and 57.69% respectively. In contrast, the compost showed 1.58, 1.50, 1.86 and 2.41 fold increases in electrical conductivity, total nitrogen, phosphorus and potassium respectively after 90 days of working of *Perionyx sansibaricus* as compared to their initial levels (Fig 1).

Both control and experimental bedding containing castor straw plus cow dung inoculated with earthworms exhibited decline in pH, organic carbon and C/N ratio during composting period (Fig 1). Decomposition of organic matter leads to formation of ammonium ions and humic acids and these two components have exactly opposite effects on the pH. Presence of carboxylic and phenolic groups in humic acids lowers the pH, while ammonium ions increase the pH of the system. Many studies showed reduction in pH of vermicomposting of various biowastes mixed with different proportions of cattle dung [20-23], [34]. In contrast, increase in pH of vermicompost amended with cattle manure has been recorded by Gong *et al*. [35]. Several metabolic components like body fluid, mucus, and excretory products are added by the worms. Decomposition of organic matter and relative loss in total organic carbon by respiratory activity of microbes and earthworms and increase in total nitrogen during the vermicomposting improve the final product [36-37]. Boruah *et al*. [19] reported decrease of C/N ratio and humification index, enhancement of nutrients profile, nitrogen fixing, phosphate and potassium solubilizing bacterial population in the vermicomposting of citronella bagasse and paper mill sludge mixture accompanied by *Eisenia fetida*. Electrical conductivity, total nitrogen, phosphorus and potassium increased during the decomposition process in both, control and earthworm inoculated bedding materials. During vermicomposting, plant nutrients released in the available form may be responsible for increase in EC. The electrical conductivity increases at the time of vermicomposting because of mineralization and the enhancement of soluble salt levels [35]. Nitrogen is an essential building block and its enhancement is attributed by the mineralization of amino-acids containing plant residues and ammonium nitrogen conversion [38]. During the vermicomposting process, earthworms and microorganisms produce a variety of enzymes including amylase, invertase, phosphatase, protease, urease, xylanase, and cellulose that are strongly involved in nitrogen mineralization [39-40]. The present findings are supported by the results of Daman *et al*. [41] who recorded increase in amount of total nitrogen, available phosphorus and exchangeable potassium while a decrease in pH and C/N ratio during recycling of rose flower waste through vermicomposting from 0 to 90 days using *Eisenia fetida* and *Eudrilus eugeniae*. Increases in nitrogen due to vermicomposting were also reported by [42-43].

Previous reports indicated that nitrogen enriched compost is produced by earthworms during vermicomposting after addition of cattle dung [23], [44]. Earthworms can transform insoluble phosphorus into soluble phosphorus during the composting. The gut of the earthworms mainly contains phosphorus solubilizing microorganisms which are frequently involved in the phosphorus mineralization [45]. Kaviraj and Sharma [46] documented, increase in potassium level due to decomposition of organic matter by biological activity of earthworm that exchange insoluble potassium into soluble potassium. During waste decomposition by vermicomposting an increase in profile of nitrogen, potassium and phosphorus were reported by Raja *et al*. [47] and also by El-Jawaher and Bin Dohaish [48]. Karmegam *et al*. [49] conducted an experiment on vermin-transformation of coir pith (CP) into enriched vermifertilizer employing *Eisenia fetida* and *Eudrilus eugeniae* and documented a significant reduction in cellulose, lignin, organic carbon, C/N ratio, C/P ratio and an increase in plant nutrients as compared to control. Present findings are also supported by reports of various other investigators [18], [20-23], [34], [48], [50-51] who recorded significant increase in total NPK but decline in pH, organic carbon and C/N ratio in vermicomposting process. Since the vermicompost is a nutrient rich material, it will have a positive effect on various crops grown in agricultural fields.

CONCLUSION

Vermicomposting of castor (*Ricinus communis*) straw blended with cow dung and using two epigeic earthworm species (*Eisenia fetida* and *Perionyx sansibaricus*) showed significant changes in physiochemical parameters of worm worked bedding. *Eisenia fetida* decomposes and converts bedding materials into simpler assimilable components faster than *Perionyx sansibaricus*. Based on the conversion rate we have calculated the efficiency of particular earthworm species in the amended castor straw with cattle dung bedding. The decomposition efficacy of *Eisenia fetida* was higher than *Perionyx sansibaricus.* This indicated that both the worms were efficient in stabilizing castor straw into compost however, *Eisenia fetida* was better. Therefore, vermicomposting of castor waste amended with cow dung (1:1, w/w) may be popularized for production of nutrient rich vermifertilizer in arid and semi-arid regions.

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