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Bioconversion of Solid Waste into Nutritional Rich Product for Plants by using *Eudrilus eugeniae*

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ABSTRACT

Rise in human population and financial growth complicated the solid waste disposal worldwide and increase the possibilities of dispersion of diseases. This issue can only be solved through fusion of eco-friendly efficient techniques. In the present study, the efficacy of *Eudrilus eugeniae* has been tested for the food, medical and paper waste decomposition. During vermicomposting, *Eudrilus eugeniae* development was recorded with significant increase in length, weight, cocoon production, and adult individuals in final compost. Results of 60 days study suggested positive impact of vermicomposting on waste decomposition. Vermicompost of food waste (VFW) resulted with organic carbon 21.67%, 1.98% nitrogen content, and phosphate 0.59 mg/ml. Vermicompost of medical waste (VMW) analysis resulted with organic carbon 15.3%, 1.17% nitrogen, and 0.54 mg/ml phosphate. Whereas physico-chemical results of vermicompost of paper waste (VPW) showed 18.67% organic carbon, 1.39% nitrogen, and 0.79 mg/ml phosphate. The nutritional values of produced vermicompost from different solid wastes were estimated. The VFW resulted with increased nutrient contents than the VMW and VPW. Therefore, decompositing of waste materials by earthworms is the preeminent concept of nutrient renewal from green waste.

Keywords: Cocoon, *Eudrilus eugeniae*, juvenile, medical waste, solid waste management, vermibed

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INTRODUCTION

Increase in population leads to creation of undesirable effect on environment i.e. variability in waste type generated from urban and rural background, food problem, cutting of forests for cultivation, industrialization, air pollution and

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global warming (Gupta et al., 2015). Waste produced due to urban and rural consumption are undesirable pollutants to the environment (Khajuria et al., 2010) and sometimes could even be a health menace (Boffa et al., 2010). The rate of waste generation is an index of socio-economic development and economic prosperity of the region (Sudkolai & Nourbakhsh, 2017). Solid waste is generated from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction and demolition sites, and agricultural activities (Gupta et al., 2015). In the solid waste stream, waste is broadly classified into organic and inorganic.

It has been reported that India produces approximately 960 million tonnes solid waste every year in form of by-products produced by various sectors i.e. industry, municipal, mining, agriculture and other process in form of organic waste (roughly 350 million tonnes agricultural), inorganic waste (around 290 million tonnes from industry and mining) and hazardous waste (approximately 4.5 million tonnes) (Pappu et al., 2007). In India, per capita waste generated is ~0.4 kg per day having compostable matter more than 50-60% (Gupta et al., 2015).

Earthworms are ecological engineers (Suthar, 2010). These organisms impact the channelization of various nutrients in soil. They are responsible for construction of physical and chemical structures of soil that effect availability of nutrients and resources for other organisms habitat in soil (Gómez-Brandón & Domínguez, 2014). It is reported in literature that presence of earthworms in soil impart a positive effect on available number of bacteria (around hundred times higher bacteria reported) than non-worm based soil (Hussain et al., 2016). About 2,350 years ago Aristotle had said, "Earthworms are intestines of the earth" (Yadav & Mullah, 2017). Darwin also supported the Aristotle statement: "No other creature has contributed to building of earth as earthworm" (Feller et al., 2003). Vermiculture is a biological process belonging to breeding and increasing earthworms in natural system. It has the ability to reduce biological and non-biological waste, biofertilizer production and range of potential applications for future (Karimi et al., 2017).

Vermicomposting is a natural biological process that stabilize the organic energy-rich contents available in raw substrate into vermicompost through the mutual activity of microorganisms and earthworms (Bhardwaj & Sharma, 2015). It generally does not have any hazardous consequence on plant, animal and environment. Vermicompost has higher range of available nutrients in plant utilizable form i.e. carbon, nitrates, phosphates, potassium, calcium carbonate and magnesium derived from the wastes (Gupta et al., 2015). Availability of vermicompost in soil enhances aeration and texture of soil by increasing soil porosity. However, it also enhances water holding ability of soil due to higher organic content (Suthar, 2010). Vermicomposting process can be carried out by using several earthworm species

(Manyuchi & Whingiri, 2014) i.e. *Drawida willis*, *Megascolex mauritii*, *Eisenia andrei*, *Perionnyx excavatus*, *Lampito mauritii*, *Eudrilus eugeniae*, *Eisenia fetida* and *Lampito rubellus*. Vermicompost has large particulate surface areas that provide numerous micro sites for microbial activity and for the strong retention of nutrients (Pathma & Sakthivel, 2012). Vermicompost consistently improves biological functions in soil which inturn can trigger seeds germination, flowering,plant growth and yield, independent of nutrient availability (Pattnaik & Reddy, 2010). Gut activity of earthworms (Huang & Xia, 2018) changes the physical and chemical composition of soil. This chemical change can be notified in form of plant growth regulators, plant growth hormones, and humates. It appears that activity of earthworms on organic waste initiate the conversion of organic waste in to various plant hormones i.e. cytokinins and auxins and humic acid (Pathma & Sakthivel, 2012).

The attempt of the present study was to review the outcome of earthworm on various types of solid waste (food, medical, and paper) and nutritional value in final vermicompost.

MATERIALS AND METHODS

Vermibed preparation was done at Bhojia Institute of Life Sciences, Baddi, Himachal Pradesh, India (latitude 30° 57' 7.4592'' N and longitude 76° 46' 32.358'' E). In present study, earthworm (*Eudrilus eugeniae*) was collected from vermicomposting centre, located at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P., India (latitude 32° 6' 0.9828'' N and longitude 76° 32' 48.3108'' E). During complete study, all vermibeds were regularly monitored for moisture content and fulfilment of water requirement was achieved continuously by water spraying.

Solid Waste

Collection of food waste for our research was done from nearby restaurants (30° 58' 1.7292'' N 76° 45' 39.5748'' E and 30° 56' 55.4208'' N 76° 48' 7.8732'' E) and student mess (latitude 30° 57' 7.4592'' N and longitude 76° 46' 32.358'' E) of Bhojia Institute of Life Sciences (BILS), whereas hospital/medical waste in form of used cotton and bandages was acquired from Bhojia General Hospital situated at Bhojia campus, Baddi, Himachal Pradesh (India). Hospital waste was properly sterilized in autoclave before application in vermibeds (Karnwal & Kumar, 2012). Paper waste for our study was collected and screened from municipal waste. The food, hospital and paper waste was shredded by waste shredder before application in vermibeds. The moisture amount of all vermibeds was kept at about 55%.-75% (Pattnaik & Reddy, 2010).

Experimental Design

Research was carried out in form of three different treatments of vermibeds (VFW, VMW and VPW), prepared by adding food, medical and paper waste separately with cow dung in 3:1 ratio. One standard/control treatment (SS) was also placed for comparing

effectiveness of vermicomposting. Plastic tubs of radius 33 cm and depth 25 cm was used for vermibed preparation.

Treatment VFW. Treatment VFW vermibed was prepared by the addition of soil, food waste in different levels. Base level was prepared with 2 cm depth of natural garden soil, next level (2 cm depth) was constructed with food waste slurry, third level with natural garden soil (8 cm of depth), second last level was again with food waste slurry (6 cm depth), and thin soil layer in upper most level.

Treatment VMW. Second vermibed was framed with used sterilized hospital or medical waste (used cotton and bandages) in 2nd level and 4th level (2 cm and 6 cm depth), while sterilized natural garden soil in third and uppermost level (8 cm and 2 cm depth) whereas base level was setup with natural garden soil having 2 cm thickness.

Treatment VPW. Treatment VPW vermibed was setup with five layer system. Base level was constructed with natural garden soil having 2 cm thickness, second and forth level with paper waste (2 cm and 6 cm depth) while third and uppermost layer with garden soil (8 cm and 2 cm of depth).

Treatment SS. One treatment was constructed without solid waste and earthworms, which worked as control (SS).

All four setups were left for 15 days for decomposition through natural micro flora. Moisture content in all vermibeds was preserved constantly by sprinkling sterilized water (Sim & Wu, 2010). After 15 days of Pre-decomposition, all three treatments (VFW, VMW and VPW) were inoculated with 50 healthy earthworms (*Eudrilus eugeniae*). This complete setup was retained for sixty days until fine granular vermicompost was ready. After 60 days of compositing, chemical estimation of vermicompost for each treatment against control was carried-out (Sharma & Garg, 2018). Quality of vermicompost was governed by various factors i.e. pre-processing time, pH, moisture content, organic carbon content, sulphate content, calcium carbonate content, chloride content, inorganic phosphate contents, temperature, and the maturation stage (Pattnaik & Reddy, 2010).

Physico-chemical Analysis of Samples

pH. The pH of the final compost was determined (Azarmi et al., 2008) using pH Meter (CD 510, WPA). The pH is defined as the negative log to the base 10 of the H^+ ion concentration (Sim & Wu, 2010). Air-dried compost (20 g), sieved through a 2mm filter, was transferred to a sterilized 200ml beaker to in which 50ml of sterilized distilled water [soil: water, 1:2.5 (w/v) ratio] was added (Sim & Wu, 2010). The contents were stirred intermittently and the sample suspension was again stirred just before taking the reading. After shaking the solution for 30 min pH was measured with pH Meter (CD 510, WPA) fitted with a glass electrode.

Electrical Conductivity. Electrical conductivity (EC) of the samples was determined by taking sample water suspension at 1:2 ratio and the electrical conductivity was measured in terms of the resistance offered to the flow of current using a conductivity bridge. Electrical conductivity was expressed as mS/cm (Hawkes, 2009).

Moisture % Content. The moisture value was calculated as a percentage for compost and vermicompost (Fudholi et al., 2012). Ten gram of fresh soil/compost was weighed (w1) and oven dried for 24 hours at 105°C. After 24 hours, final weight (w2) of dried vermicompost was estimated through digital weighing machine. Percent Moisture content was calculated by applying w1 and w2 values in following formula:

Moisture content (%) = (w1-w2)*100/w2

Total Organic Carbon (TOC) (Modified Walkley-Black Procedure, Sato et al., 2014). Five gram compost was ground up so as to sieve through 0.5 mm mesh sieve. This fine sieved compost (500 mg) was transferred in a 1000 ml beaker. In this beaker, 10 ml of 0.166 mol $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4 were added by directing steam into the suspension. Mixing of all contents was done gently and carefully. After 30 minute of stand at room temperature, 30 ml distilled water with 0.2 ml o-phenanthroline indicator was added in the mixture. Titration of mixture was done by using $FeSO_4$ solution until solution colour changed to greenish and then changed to dark green or greenish blue occur (Initially the colour was dark brown). At the end point the color changed quickly from greenish blue to reddish brown (Walkley & Black, 1934).

% C = M x V1-V2 / weight of sample (g) × 0.39

where,
M = molarity of the $FeSO_4$ solution.
V1 = $FeSO_4$ volume (ml), required for blank
V2 = $FeSO_4$ volume (ml), required for sample
$0.39 = 3 \times 10^{-3} \times 100 \times 1.3$, where 3 is equivalent weight of C and 1.3 is the factor explained below.
The factor of 1.3 was based on the assumption that their was77% recovery.

Total Nitrogen (N) Content. Estimation of Total N value in prepared vermicompost was done by Kjeldahl method (Yadav et al., 2013). Final vermicompost was air dried and ground to obtain fine powder. One gram of fine powder vermicompost was transferred in Kjeldhal's digestion flask and enriched with 3 g of digestion mixture (Potassium Sulphate: Cupric Sulphate: Selenium in the ratio of 100:20:1) with 10-15 ml concentrated H_2SO_4. This mixture was digested for a period of time until a bluish-green residue was appeared, followed by cooling of flask contents by adding distilled water to make total volume up to 100ml.

After cooling, 10 ml of digested mixture was transferred in a micro-distillation flask with 10ml of distilled water. The outlet of the condenser was dipped in 25 ml of 4% boric acid solution in a 250 ml conical flask. Before starting the distillation process, 10 ml NaOH (40%) was added in distillation flask and the mixture were distilled. After distillation, boric acid was titrated through 0.05N H_2SO_4 till pink color obtained. A blank was also run in similar manner and final % of N in samples was calculated by using following formula:

$$\%N = \frac{\text{(Burette reading)} \times \text{(Normally of acid)} \times (0.014) \times \text{(Volume made of digested sample)} \times 100}{\text{(Weight of sample taken)} \times \text{(Aliquot taken for distillation)}}$$

Inorganic Phosphate Content. Phosphorus is one of the key nutrient required by all living beings (Dharni et al., 2014). In natural environment distribution of phosphorus is majorly found as phosphate form. It is the 11th utmost eco-rich component on the upper layer of the soil (Gallego et al., 2001). The increased amount of phosphate in soil/ compost plays the active role for the positive growth of plants.

In present study inorganic phosphate concentration in all treatments were measured by spectrophotometric method (Mahadevaiah et al., 2007) with some modification. Air dried compost was mixed with 0.002N H_2SO_4 in 500ml sterilized conical flask to make 10 ml 0.5% (w/v) homogenized suspension by using magnetic stirrer. After 30 min of proper mixing suspension was carefully sieved by using Whatman 1442-125 Ashless Grade 42 Quantitative Filter Paper. Filtered soil extract was used for Inorganic phosphate determination in all samples.

In a conical flask, 5 ml of soil filtrate was mixed with 0.2 ml $(NH_4)_2MoO_4$ solution and one drop of $SnCl_2$ solution (Mahadevaiah et al., 2007). Mixture was stand alone for 10 minutes for the development of blue colour and absorbance was recorded at 690 nm with UV-VIS Spectrophotometer. Deionised water blank was also run in similar manner. Inorganic phosphate estimation was carried out with following formula:

Inorganic phosphate contents in the all treatments was determined by comparing determined phosphate content against standard curve of potassium dihydrogen phosphate (P, 0-1 mg/l) at 690 nm wavelength.

Potassium Estimation. Potassium estimation in vermicompost was done through flame photometry method (Zebec et al., 2017). Ten gram of air-dried vermicompost was ground in fine particles and sieved with Whatman No. 40 filter paper. Filtered 5 g fine vermicompost was mixed in 25 ml 1N $NH_4CH_3CO_2$ for 10 minutes on a stirrer for uniform shaking and filtered with Whatman No. 40 filter paper. Final volume of filtrate was made up to 100ml by adding ammonium acetate solution. Photometeric analysis was performed by using 5 ml of

ammonium acetate supplemented sample. *Potassium* chloride solution was applied as standard for estimation of Potassium content.

Chloride Assay. Twenty gram of compost was added in 100 ml of distilled water to make 1:5 solutions in 250 ml conical flask. The contents of flask was stirred for one hour at regular intervals and filtered with *Whatman Grade 50 filter paper by using funnel in 250 ml beaker. Filtered suspension (50 ml) was mixed with 2 ml of* K_2CrO_4 solution and titrated with 0.02N $AgNO_3$ till a stable red circle observe (Karnwal & Kumar, 2012).

% Chloride = N of $AgNO_3$ (ml) × 1000 × 35.5/ soil solution (ml) × 2

To convert the values in mg/100g, multiply the values in % with 1000

Calcium Carbonate Test. Five gram compost was ground up so as to sieve through 0.5 mm mesh sieve. Sieved compost was added in a 500 ml conical flask with 100 ml of 1M HCl per litre of solution. The contents of flask were left overnight at room temperature. After overnight incubation, contents were centrifuged into 100 ml centrifuge tubes at 2000 x *g* for 10 minutes. Ten millilitre of supernatant was mixed with 25 ml distilled water and 0.1 ml phenolphthalein in a 250 ml conical flask. This mixture was titrated with 0.5M NaOH solution (Yadav et al., 2013).

CaCO3 % = 50N x a-b/S

where,
a = ml NaOH used for blank
b = ml NaOH used for soil samples
S = weight of dried soil samples
N = concentration of soda /solution mol/l

Sulphate Test. Sulphate is another important nutrients required by plants after nitrogen and phosphates. Requirement of sulphate content for plants is very low in amount. Twenty gram of compost was mixed in 100 ml distilled water in 250 ml conical flask. This mixture was regularly stirred over magnetic stirrer for one hour. Compost suspension was filtered with Whatman No.50 filter paper to get turbidity free solution (Mussa et al., 2009). Analysis of sulphate was carried out with 100 ml of filtered solution in a conical flask supplemented with 5 ml of conditioning reagent. This mixture was agitated over magnetic stirrer and during stirring, 0.2-0.3 g $BaCl_2$ crystals was added. After stirring, without any delay, the solution was poured in a 4 cm silica cell and absorbance was recorded at 420 nm through UV-VIS spectrophotometer.

Turbidimetric method: % SO_4 = SO_4 mg/l soil solution/2000

To convert values in mg/100 g, multiply the results in % with 1000

Standard curve of sulphate constructed by measuring absorbance of sodium sulfate ranging from 0.0-50.0 mg/l at 420 nm through UV-VIS spectrophotometer with

interval of 5 mg/l. This standard curve was used to estimate sulphur contents in the samples.

RESULTS AND DISCUSSION

Earthworm Development and Production Efficiency

The development characteristic of *Eudrilus eugeniae* in treatments VFW, VMW and VPW revealed that length was increased by 26% in VFW, 17% in VMW and 20% in VPW, whereas individual weight gained at the end of vermicomposting by *Eudrilus eugeniae* in each treatment was 428.0, 187.3, and 221.4% in VFW, VMW and VPW treatment respectively (Table 1). Cocoon production rate in VFW was more than that of VMW and VPW treatments. The earthworm production per cocoon was 68.2 in VFW and 18.0% VPW than that of VMW treatment. VMW treatment showed higher number of juveniles 219.4% compared to VFW and 47.4% compared to VPW treatment. Adult earthworm count was more in VFW compared to other two treatments. The production of cocoons, juveniles, and adults of *Eudrilus eugeniae* was higher in food waste vermicompost than that of medical and paper waste based vermicompost, these findings suggest that food waste worked as nutritious medium for the earthworm development (Lalander et al., 2015). The higher body mass of inoculated worms was observed in all three treatments during vermicomposting phases (Table 1), which resulted because of nutrients available in treatment mixture or environmental conditions (Yadav et al., 2013). Cocoon production was better in food waste, whereas paper waste treatment also showed good cocoon production rate in comparison to VMW treatment. Our results are also supported by other studies (Kuntz et al., 2013; Suthar, 2009). The higher numbers of cocoons, juveniles, and adults were collected from the vermicompost processed by using food waste plus cow dung.

Table 1
Development parameters of Eudrilus eugeniae *in treatments during vermicomposting*

Development parameters		Treatments supplemented with different solid waste		
		VFW	VMW	VPW
Mean Individual length	Initial (cm)	14.3 ± 0.02	14.3 ± 0.02	14.3 ± 0.02
	Final (cm)	18.0 ± 0.05	16.7 ± 0.04	17.2 ± 0.1
Mean Individual weight	Initial (g)	3.1 ± 0.02	3.1 ± 0.02	3.1 ± 0.02
	Final (g)	13.3 ± 0.01	5.8 ± 0.05	6.9 ± 0.04
Mean Total biomass	Initial (g)	155 ± 0.04	155 ± 0.04	155 ± 0.04
	Final (g)	2627.1 ± 0.06	841.9 ± 0.03	1070.7 ± 0.05
Mean Worm number/cocoon		2.4 ± 0.06	1.4 ± 0.01	1.7 ± 0.07
Mean Juvenile number at the end		36 ± 0.04	115 ± 0.04	78 ± 0.04
Mean Adult number at the end		198 ± 0.05	145 ± 0.07	156 ± 0.02

Values represent the mean of three replicates ±standard error of the mean

Physico-Chemical Analysis

After 60 days of vermicomposting, compost of all treatments was chemically analyzed for various physico-chemical analysis. Compost analysis revealed that change in waste material severely impacted on the nature and chemical composition of finally produced vermicompost (Sharma & Garg, 2018). Various parameter i.e. pH, Electric conductance, % moisture content, Temperature, Organic carbon content, Nitrogen content, Inorganic phosphate content, Potassium content, , Chloride content, Calcium carbonate, and sulphate content were analysed in final vermicompost of treated and non-treated samples.

pH. pH analysis of vermicompost showed a variation in final pH from 7.33 to maximum 8.86. Treatment VFW vermicompost showed pH 8.86 whereas VMW and VPW recorded with 8.68 and 8.79 pH, respectively (Figure 1). It was observed that control treatment had neutral pH. Change in pH, particularly happened due to the activity of earth worms, and deposition of nutrients increased in final vermicompost that changed the pH from neutral to basic (Pattnaik & Reddy, 2010).

EC Value. In our study, EC value was found to increase in comparison to control treatment (Figure 2). This rise in EC during compositing and vermicomposting happened due to decomposition of organic waste (Pattnaik & Reddy, 2010) and increased the availability of exchangeable cationinc minerals i.e. Ca, K, P and Mg in compost and vermicompost (Pérez-Godínez et al., 2017).

% Moisture Content. In present study, all treatments (instead of SS) had % moisture value between 55 to 85% (Table 2). Nigussie et al. (2016) reported that 70-85% moisture content played an important role for the good and luxuriant growth of *E. Eugeniae* during organic waste decomposition. Manyuchi and Whingiri (2014) also observed the effect of good moisture value on the growth of earthworm and waste decomposition rate. Earlier research (Jadia & Fulekar, 2008) also showed higher microbial activity during the availability of 60–70% moisture in samples, whereas decrement of moisture value negatively impacted the activity of bacteria and fungi during decomposition process. In

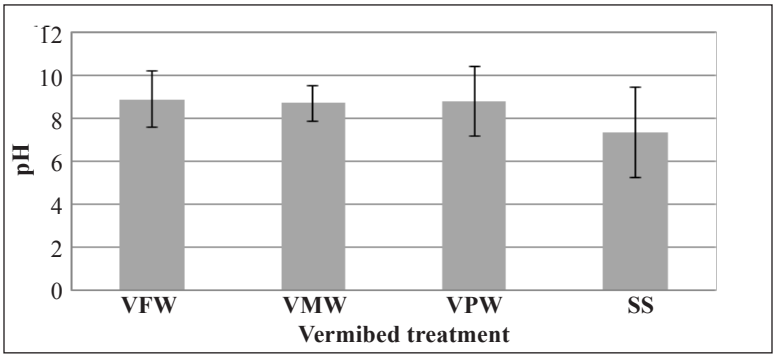

Figure 1. pH value in final vermicompost after 60 days of vermicomposting (VFW: vermicompost of food waste; VMW: vermicompost of medical waste; VPW: vermicompost of paper waste; SS: standard sample)

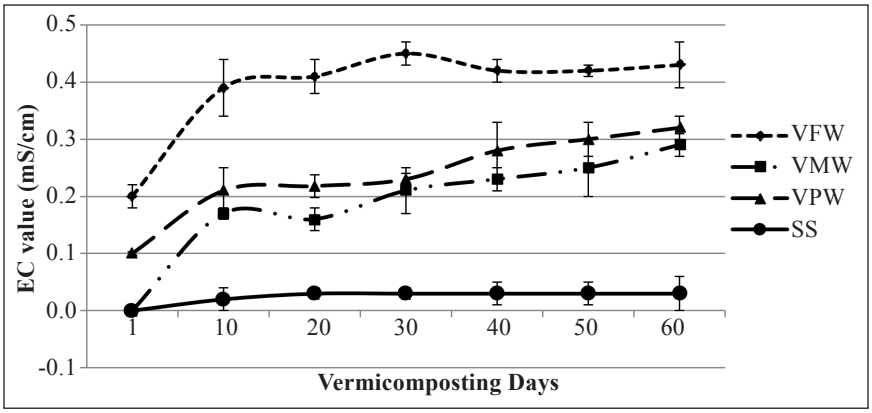

Figure 2. EC value in different vermicompost during vermicomposting

our study, vermicompost samples showed higher % moisture value due to their high absorption capacity than the compost and substrate (Table 2).

Temperature. It was observed during different experiment phases that all treatments showed a higher temperature at the start of experiment because of degrading activity of mesophilic bacteria and fungi during initial compositing process (Jadia & Fulekar, 2008), while at the end of experiment a decrease in temperature recorded (Singh et al., 2003). In first mesophilic phase temperature increased up to 40°C because of oxidative breakdown of organic matter available in all treatments (Pérez-Godínez et al., 2017) and then due to activity of thermophilic bacteria and fungi it elevated from 40°C to 60°C when most of the organic matter degradation and sharp depletion in oxygen occurred (Nigussie et al., 2016). Once anaerobic decomposition of waste completed, maturation phase of compost initiated with the decrement of compost temperature (cooling phase) (Tognetti et al., 2005) which happened due to less bacterial action and regular sprinkling of water.

Organic Carbon by Wet Digestion. Available carbon in substrate is mainly used in compositing and vermicomposting process by earthworms and bacteria as a

Table 2
% moisture value of final vermicompost

Vermicomposting treatments	Initial sample weight	Sample Dry Weight 105°C	Net moisture value	% moisture value
	(w1) g	(w_2) g	(w_1- w_2) g	(%)
VFW	10± 0.02	5.8± 0.03	4.2± 0.01	72.4138
VMW	10± 0.04	6.5± 0.02	3.5± 0.02	53.8462
VPW	10± 0.02	6.1± 0.05	3.9± 0.03	63.9344
SS	10± 0.02	8.1± 0.01	1.9± 0.01	23.4568

Values represent the mean of three replicates ±standard error of the mean

source of energy (Pérez-Godínez et al., 2017), resulting in decrement of total organic carbon of final vermicompost. In present study, it was observed that compositing and vermicomposting process caused reduction of total organic carbon during the passage of time. These results are favoured by other earlier studies (Ndegwa & Thompson, 2000; Pérez-Godínez et al., 2017). However, the TOC content was 21.67%, 15.33%, 18.67%, 12.33% in the VFW, VMW, VPW and SS after completion of vermicomposting, respectively (Figure 3). The organic carbon is converted in CO_2 due to microbial respiration and decomposition of organic contents available in raw material (Kharrazi et al., 2014). Some part of organic carbon is also assimilated in form of biological mass of microbes and earthworms (Pérez-Godínez et al., 2017).

Total N Content. Total nitrogen content consists two inorganic form of nitrogen NH_4–N and NO_3–N in final vermicompost (Adhikary, 2012). In present study, vermicompost prepared by in all treatments showed a considerable variation in N content. Total % nitrogen content was 1.98% in VFW followed by medical waste 1.17% and 1.39% in VPW vermicompost, respectively (Figure 4). Tripathi and Bhardwaj (2004) reported an increase in available nitrogen in final vermicompost in variety of biological forms i.e. mucus, nitrogenous biological

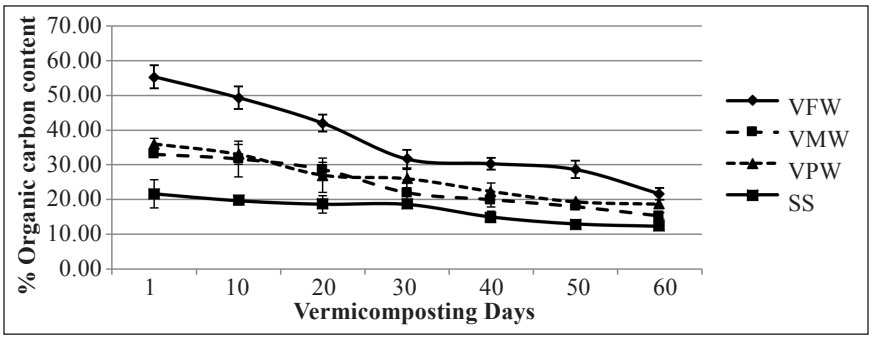

Figure 3. % carbon content in different treatments during vermicomposting process

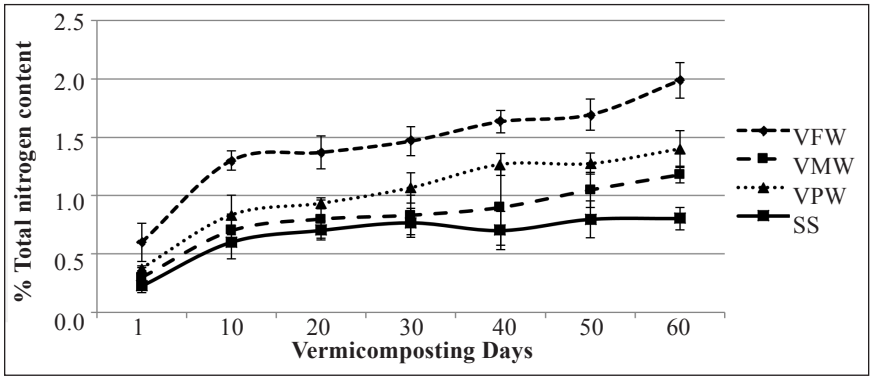

Figure 4. % Nitrogen content during vermicomposting process in different treatments

excretory compounds, decaying dead tissues of worms, hormones and enzymes secreted by earthworms. Increment of nitrogen content may also be possible because of mineralization of total organic carbon containing proteins (Hanc et al., 2017).

C/N Ratio

The C:N ratio was decreased in end product after 60 days. Initially value of C:N ration was higher due to availability of sufficient amount of carbon and nitrogen in pre-compost mixture (Yadav et al., 2013). Lower C:N ratio in final vermicompost reflects the range of changing in carbon and nitrogen content during vermicomposting process. It was observed that initial value of C:N ratio decreased to final value in all treatments (VFW from 92.22% to 10.91%, VMW from 110 % to 12.99%, VPW from 95.58% to 13.34% and SS from 97.01% to 15.35%) as shown in Figure 5. The reduction in C:N ratio throughout vermicomposting happens due to elevated oxidation of organic matter and may possibly be attributed to raise in the earthworm numbers which contributes towards quick reduction in organic C (Pattnaik & Reddy, 2010). The emission of portion from the carbon as CO_2 during the course of breathing, synthesis of mucus and N excrements, raises the amounts of N and decreases the C:N proportions (Adhikary, 2012).

Inorganic Phosphate Content. The total inorganic phosphate content in four treatments ranges from 0.51 to 0.79 mg/ml. It was found that total inorganic phosphate content in final vermicompost was higher compared to initial amount in various substrates (Adhikary, 2012). In present study, minimum inorganic phosphate value was reported 0.51 mg/ml in SS (control) whereas maximum amount was 0.79 mg/ml in VPW final vermicompost. Enhanced inorganic phosphate content in treatments indicates phosphorous solubilization/ mineralization during compositing process (VFW 0.59 mg/ml, VMW 0.54 mg/ml, VPW 0.79 mg/ml). It has been reported by various researchers that earthworms solubilise insoluble P in the presence of P-solubilizing

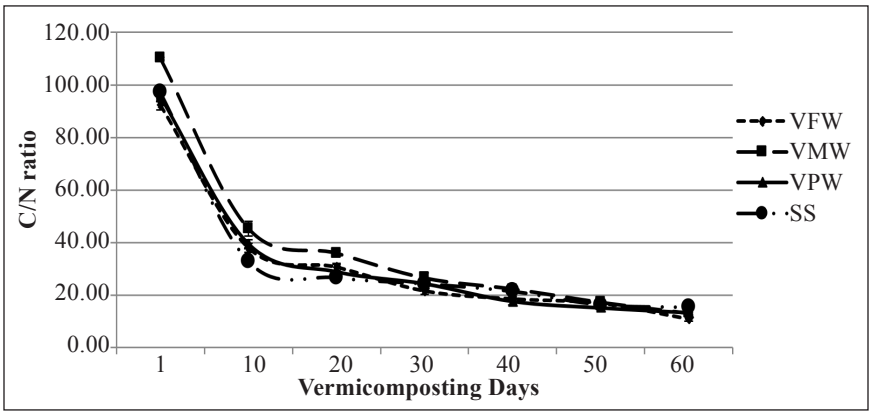

Figure 5. Change in C:N during vermicomposting

microorganisms by using phosphatases enzyme available in the gut, making it more available to plants (Karimi et al., 2017; Lim & Wu, 2016).

Table 3
Physico-chemical properties of final vermicompost in different treatments after 60 days of vermicomposting

Treatments	Inorganic phosphate concentration (mg/ml)	Chloride (mg/100g)	Calcium carbonate (%)	Sulphate (mg/100g)
VFW	0.59± 0.02	60.86± 0.04	0.11± 0.01	13.93± 0.05
VMW	0.54± 0.04	44.12± 0.05	0.09± 0.003	7.5± 0.02
VPW	0.79± 0.03	41.79± 0.02	0.14± 0.01	9.64± 0.01
SS	0.51± 0.002	38.57± 0.03	0.08± 0.004	6.96± 0.01

Values represent the mean of three replicates ±standard error of the mean

Potassium Content. The present findings recorded with the higher amount of K in VFW and VPW vermicompost (Figure 6). VMW and SS recorded with least K content in final vermicompost. Vermicomposting is one of the most efficient method for releasing maximum K content from organic material (Yadav et al., 2013). Releasing of K in vermicompost mainly happens due to enzymatic decomposition and grinding of organic substrate in earthworm gut, which may have caused its increase compared to the simple compost (Garg et al., 2006). The microorganisms present in the worm's gut probably converted insoluble K into the soluble form by producing microbial enzymes (Mahboub Khomami et al., 2016)

Chloride Content. Chloride play a critical role in plant development so its availability in soil matter allot for agriculture (Yaish et al., 2015). Chloride in soil is available in soluble form and predominantly dissolved in the soil water. However, it was demonstrated that higher Cl concentration in plant tissue could become toxic to plants, and stopped the agriculture practices in saline regions (Karnwal & Kumar, 2012). Our study

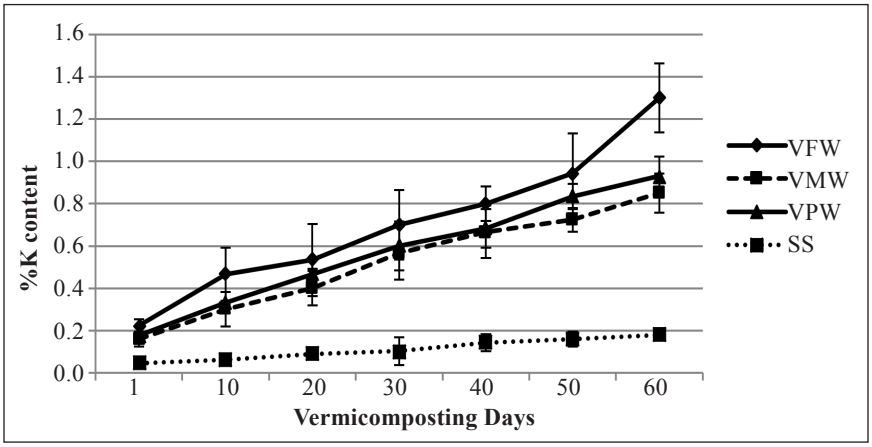

Figure 6. % Potassium content during vermicomposting process in different treatments

showed that in the various vermicompost samples (Table 3), maximum chloride content was recorded in VFW treatment (60.86 mg/g), followed by VPW (41.79 mg/g) and VMW (44.12 mg/g) whereas minimum chloride content was recorded in SS vermicompost (38.57 mg/g).

Calcium Carbonate Content. In present study, amount of calcium carbonate ranges from 0.08 to 0.14 % in final vermicompost (Table 3). Higher Ca content in VFW, VMW and VPW vermicompost relies on the enzymatic activity of carbonic anhydrase naturally available in calciferous glands of *Eudrilus eugeniae* that give rise calcium carbonate on the fixation of carbon dioxide (Yadav et al., 2013). Out of four treatments, minimum calcium carbonate was 0.08% in SS vermicompost whereas maximum Ca amount was recorded 0.14 % in VPW vermicompost followed by VFW and VMW treatments.

Sulphate Test. Sulphur is essential for optimal plant growth and development (Lim & Wu, 2016). It is one of the 17 essential plant nutrients. In natural system, plants are not able to consume sulphur in elemental form (Quilchano et al., 2002), They only consume sulphur from soil in sulphate form ($SO4^{2-}$). In present study, considerable increase in sulphate content appeared in final vermicompost (Table 3). Higher sulphate content was recorded in VFW followed by VPW vermicompost. Least level of sulphate was observed in SS treatment.

CONCLUSION

Bioconversion of solid waste by the use of earthworm into nutrition rich vermicompost can become an economical process for the farmers and local environment cleanup bodies, saving substantial amount of money and environmental security affected by deposition of solid waste in environment. It is concluded from present study that among the three type of solid waste (food waste, medical waste and paper waste), food waste provided best growth and nutritional value in produced vermicompost whereas paper and medical waste while exhibiting lower amount of nutrient value in vermicompost, they were still better than normal soil. The use of *Eudrilus eugeniae* is a suitable biological process for the bioconversion of food, medical and paper waste into organic nutrient rich compost that can decrease the burden of artificial fertilizers and enhance natural soil fertility by providing various plant nutrients in agriculture field.

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