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Biogeneration and physico-chemical properties of panchagavya fortified chicken feather vermicompost

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Abstract

An enormous amount of chicken feather waste materials released by the poultry industry creates severe environmental pollution. Vermicomposting is an eco-friendly way to degrade chicken feather waste along with microbial mixture (Panchagavya). Chicken feather waste was pre-decomposed by mixing it with fresh cow dung (T1), dry cow dung (T2), and Panchagavya (T3). Among these, T3 exhibits rapid deterioration of chicken feather waste and seven combination T3 substrates (E0-E6), taken for the vermicomposting process by *Eudrilus eugeniae* in 60 days. Scanning Electron Microscopy/Energy Dispersive Spectroscopy (SEM-EDS) and Fourier Transforms Infrared (FT-IR) Spectroscopy are used to assess compost maturity. The result shows that E1 (0.050:1 ratio) shows various functional groups, rich nutrients, and necessary acids than other combinations. For large-scale commercial vermi-stabilization of chicken feather waste, the E1 combination is suitable for manure production and thereby enhances soil fertility, agricultural production.

Introduction

In the twenty-first century, the utilization of poultry-based products (e.g., eggs and meat) has drastically increased in Asian and European countries. Meat (chicken) is a common source of protein for children and adults. Consequently, the poultry industry is a rapidly growing industry worldwide and economically profitable (Oakley et al. 2014). About 24,000 million tons (MT) of broiler chickens are killed per annum, producing 8,500 MT of chicken feathers globally. In addition, around 350 MT of chicken feathers is eliminated during the meat process by the Indian poultry industries (Agrahari and Wadhwa 2010). The poultry feathers contain 90% of keratin proteins, 1% of lipids, as well as 8% of water (Tesfaye et al. 2017). The keratin is divided into two groups - (i) alpha-keratin, and (ii) beta-keratin (Bodner 1982), and cross-linked polypeptide chains (Gupta and Ramnani 2006). Apart from these, poultry feathers consist of several nutritive elements and pathogenic microorganisms. Improper disposal of poultry feathers creates severe environmental pollution, particularly water and soil pollution. Therefore, there is an urgent requirement for disposal technologies to minimize poultry feather wastes. Recently, vermicomposting employing different earthworm species has grasped the attention of environmental researchers.

The soil bio-indicators, particularly earthworms (Wang et al. 2020), can effectively break down several organic waste materials (Yuvaraj et al. 2020). In general, the vermicomposting operation involves the earthworm species and various microbial communities (Domínguez et al. 2019). The earthworms utilize the different polluted organic waste materials. The earthworms significantly alter the wastes through rapid rotation and aeration and stimulate the degradation of substrate waste materials through various digestive enzymes (Maboeta and Van Rensburg 2003). For example, the gut of the earthworms and gut-related symbionts secrete numerous enzymes, including cellulose, protease, phosphatase, amylase, urease, manase, and lipase, which efficiently stabilize the different waste materials (Ravindran et al. 2015; Gusain and Suthar 2020). The epigeic earthworm species can mainly stabilize the complex waste materials than other anecic and endogeic species, as documented by (Ravindran et al. 2021). For instance, several researchers successfully employed epigeic earthworms, such as *Perionyx excavatus*, *Eisenia fetida*, *Eisenia andrei*, and *Eudrilus eugeniae* (Yuvaraj et al. 2018, 2020). Undoubtedly, vermicomposting can degrade poultry feather waste materials, which provide the essential nutritive elements that trigger crop production. Experiments of Mazotto et al. (2011) concluded that the biodegradation of poultry feathers waste employing various microbes *Bacillus licheniformis* 1269, *Bacillus subtilis* 1271, and *Bacillus cereus* 1268 resulted in the production of nutrient-rich substrate. Likewise, Vasileva-Tonkova et al. (2009) reported that several thermo-actinomycete strains effectively degraded the complex poultry feathers, and a considerable amount of soluble protein was increased in the final substrate. The study of Mohan and Senthilkumar (2019) indicated that the composting of poultry feathers and physicochemical parameters significantly increased on the 90th day. According to the previous bench-scale reports, various microorganisms have been used to degrade poultry feather waste materials, but those methods contain several disadvantages like pH altering the microbial activities, odor production, and slow decomposition process. Also, only minimal work has been done concerning vermicomposting of poultry feather wastes. The main objectives of the present study were: (i) to collect the feather wastes from the poultry farms of Namakkal District, Tamil Nadu; (ii) to prepare the Panchagavya (microbial mixture) for pre-composting/fortification of the feather waste materials; (iii) to achieve vermicomposting of the feather wastes (pre-composted) employing *Eudrilus eugeniae* and to evaluate the physicochemical parameters.

Materials And Methods

Collection of chicken feather waste

The chicken feather wastes were collected from poultry farms in Elur, Namakkal District (Latitude 11°21'08.72 'N / Longitude 78°06'30.43 E), Tamil Nadu, India. The chicken feather wastes were packed in polythene bags and brought to our laboratory.

Preparation of Panchagavya

Cow dung (7kg) and ghee (1kg) were combined in a plastic container with a volume of 80 liters, kept for three days, and periodically stirred two times per day as adopted by Selvaraj (2006). After three days, 10 liters of cow urine, 2 liters of curd, 3 liters of cow milk, 3 liters of tender coconut water, 10 liters of water with 3 kg of jaggery, and 12 liters of well-ripened bananas were mixed twice a day for 15 days. After the filtration process through a delicate fabric, the Panchagavya was prepared according to Rakesh et al. (2017) and Sarkar et al. (2014) for fortication.

Pre-decomposition process of chicken feather waste

Fresh chicken feather waste materials are harmful to earthworm species; therefore, the pre-decomposition process was essential before the vermicomposting process. With optimum environmental factors, the collected chicken feather waste was stored in three earthen pit bags (150cm × 45cm × 30cm). Three pre-decomposition treatments (triplicate), namely T1 - fresh cow dung along with chicken feather waste (100gm /1 liter of water); T2 - dry cow dung and chicken feather waste (100gm/1 liter of water); T3 - Panchagavya mixed with chicken feather waste (100ml/ 1 liter of water). Earthen pit bags were sprinkled with water once every two days and turned up every ten days. In general, cow dung and Panchagavya contain various microbial communities which effectively degrade the fresh chicken feather waste.

Furthermore, the microbes of Panchagavya (T3) effectively stabilize the chicken feather waste material at the end of the 60th day, presented in Figure 1. Other treatments (e.g., T1 and T2) obtained a moderate level of decomposition rate. Hence, T3 substrate materials have been used for further vermicomposting operations.

Experimental configuration of vermicompost

The pre-decomposed substrate T3 was combined with cow dung in various ratios, *viz*. E0, E1, E2, E3, E4, E5, and E6, as described in Table 1, and was subjected to vermicomposting using *Eudrilus eugeniae,* commonly known as the African nightcrawler (Kinberg 1867). An experimental ratio was used for five kg of substrate mixture in plastic containers (25 cm in diameter and 40 cm in height). Furthermore, adult *E. eugeniae* of 25 numbers was released into the plastic containers. Experimental containers were kept in a cool dark place and protected by a mosquito net. Humidity was maintained at 60 to 80 percent (%) during the vermicomposting process.

Analysis of physicochemical properties

Standard methods have been used for the study of physicochemical parameters of pre-decomposed and vermicompost samples. Temperature, pH, and humidity were analyzed at intervals every ten days. At the end of the 60^{th} day, the pH, temperature, organic carbon, organic matter, and ash content of the vermicompost (E0-E6) samples were recorded. The determined pH was 1:10 (w/v) ratio of using a double-distilled water suspension of compost, and after 30 minutes of mechanical stirring, filtered through Whatman No.1 paper and analyzed by digital pH meter (Vasanthi et al. 2014). The moisture content of the vermicompost samples was oven-dried at 105ºC until it reached a constant weight (Kato and Miura 2008; Mohee et al. 2008; Unmar and Mohee 2008), and the moisture percentage was calculated using the procedure adopted by Schwab et al. (1994). The dry ash method calculated the ash content (Mohee et al., 2008; Unmar and Mohee, 2008). Total Organic Carbon (TOC) was examined by mixed samples (5g) into the crucibles and then burned for two hours in a furnace at 550ºC or until no stains of black carbon particles were formed and tested in compliance with Mohee et al. (2008).

SEM-EDS and Fourier-Transform Infrared Spectroscopy

To analyze the surface and structural morphology of the experimental chicken feather waste (or) vermicompost, a Field Emission Scanning Electron Microscope (FESEM) was used. In the 4000-400 cm-1 frequency range on a Brucher FT-27 FT-IR spectrometer fitted with software from OriginPro, an infrared Fourier (FT-IR) spectrum of the feather waste vermicompost samples was analyzed. A selection of 1 mg was combined with 100 mg KBr of spectroscopic grade and 1 MPa in pellets.

Statistical analysis

Statistical analysis was conducted using SPSS software version 26. One-Way ANOVA and Duncan Multiple Range Experiments (DMRT) were analyzed for a homogeneous data set with various parameters in pre-decomposed and vermicomposted samples of the chicken feather waste. All values at $p<0.05$ are considered statistically significant.

Results And Discussion

Decomposing of chicken feathers waste

The Panchagavya consists of various materials such as cow dung, cow urine, curd, cow milk, tender coconut water, jaggery, and bananas, which strongly stimulate the microbial populations in treatments. For example, the study of Amalraj et al. (2013) demonstrated that Panchagavya contains an affluent population of actinomycetes, various bacteria, and P-solubilizers. These microbial communities effectively stabilize the complex chicken feathers waste materials during the pre-degradation process, as depicted in Table 2. The present study demonstrates that Panchagavya contains different essential nutrients that can trigger microbial populations by fortification with substrate. Recently, Behera and Ray (2021) confirmed that various acids (e.g., malic, lactic, citric, acetic, and succinic acids) had been found in Panchagavya, which plays a pivotal role in the elimination of various soil contaminations and enhances the degradation process.

The temperature of the substrate

Analysis of temperature in composting units is essential to determining the maturity of the final substrate materials. The highest level of temperature was recorded in T3 (39.63˚C) followed by T2 (30.23˚C) and T1 (29.47˚C), respectively. The substrate temperature significantly increased during the middle stage of composting the process, and the declining temperature level was recorded at the end of the experiment. During the decomposition process, heat is eliminated through oxidative action of various microbial communities on waste materials resulting in a decline in temperature in treatments (Peigne and Girardin 2004).

Moisture

Higher moisture content was recorded in pre-decomposed chicken feather waste materials, indicating the deterioration process progression. The highest percentage of moisture recorded in T1, T2, and T3 was 85.65%, 83.50%, and 75.78%, respectively. The subsequent ten days of moisture were improved in T1 (88.43%) and T2 (86.36%). From the 60^{th} day onwards, T3 (16.81%) of moisture significantly (at $p<0.05$) decreased. During the feather composting process, moisture loss was detected, which might be due to the metabolic behavior of the species that encourage heat energy or environmental factors such as airflow over ventilation (Hogan et al. 1989). A drop in moisture content <30% triggers the treatment's biological processes, and 50-60% of moisture content is optimum for the composting process (Castillo 2004).

pH

The pH of the substrate is also an essential factor in enhancing the composting process. In the present study, there was a significant increase in the pH of the substrate. A maximum pH was recorded in T2. In the present study, a pH of 6.0-7.0 triggered bacterial growth. Experiments by Pan and Sen (2013) demonstrated that a pH range of 6.5 to 8.0 was satisfactory for microbial growth in food wheat straw composting. This pH is one of the critical factors for the degradation of chicken feather waste. On the other hand, the substrate of the T3 had low pH (6.16) because T3 contained Panchagavya, which also effectively degraded the feather waste materials.

Vermicomposting of chicken feather waste materials and earthworm's mortality

Earthworms significantly stabilize the pre-decomposed chicken feather waste materials. Notably, the gut wall of the earthworms and several symbionts secrete different digestives enzymes which effectually break down the chicken feather waste materials.

The earthworm mortality in experimental vermicomposting bins is presented in Table 3. Earthworm mortality was observed during the initial stages of the vermicomposting operation, and a maximum mortality rate was recorded in E5 and E6. Furthermore, zero percent of the mortality rate was observed in E0 and E1. According to our results, E1 (cow dung and 50gm pre-decomposed chicken feather waste) is suitable for nutrient-rich vermicompost production. Generally, the dried chicken feathers contain 91% of protein (Salminen and Rintala 2002). Protein-rich organic waste materials can release acidic compounds during the breakdown process (Steve 2017), which may affect the earthworm survival rate, as reported by Francesca (2017).

Physicochemical features of vermicomposting

With the progression of the vermicompost, the moisture content of the different combinations (CD with CFW) was improved, as described in Table 1. During the vermicomposting process, the percentage of vermicompost moisture (CD and CFW combinations) ranged from 59.89% to 75.77% (Table 4). The rapid development of various microbial communities may regulate the moisture content of substrate materials. Earthworm species quickly utilize the moistened waste materials. A reduction of pH in E5 (5.74) and a significantly at ($p<0.05$) improved level of pH were recorded in E1 (7.42) and E2 (7.49). The pH of the substrate decreases by the release of organic acids at the initial stage of decomposition (Liu et al., 2011), and bioconversion of organic nitrogen into free ammonia raises the pH of the compost (Altieri et al. 2011).

The organic carbon (OC) and organic matter (OM) from earthworm worked treatments are gradually reduced during the vermicomposting process. A maximum OC and OM reduction was recorded in E6. The repaid decrease of OC might be due to the release of CO_2 from the substrate by the joint action of earthworms and various microbial communities (Prakash and Karmegam 2010). Suthar (2006) stated that reducing OC in the vermicomposting process is also responsible for microbial respiration.

Maturity analysis of substrate through Scanning Electron Microscopy (SEM)

For the surface morphological characterization of substrate materials, SEM is one of the appropriate methods. The final vermicompost micrographs (Figure 2) indicate the smooth surface area and substantially reduce the size of the particles. In the SEM images of E0 and E1, smaller aggregates than E2, E3, E4, E5, and E6 found larger structural surface particles. Similar results were reported by Ravindran et al. (2008) and Senthil Kumar et al. (2014). Ferrarezi et al. (2013) have observed smooth semi-crystalline structured particles from composted chicken feather waste materials. Multiple workers (Al-Musallam et al. 2013; Chaturvedi et al. 2014; Jeong et al. 2010a, 2010b) detected microbes' circular and elliptical shape during the chicken feather deterioration.

Nutrient Analysis (SEM-EDS)

SEM-EDS suitable instruments to detect the various chemical elements (e.g., Ca, C, K, Cl, Mo, Fe, P, Na, Mg, N, S, Mn, Cr, and Co) from the substrate materials are presented in Table 5. The lowest carbon content was recorded in E0 (9.58%) and E1 (10.74%). Loss of TOC was achieved by the respiration of microorganisms and the consumption of organic compounds by microorganisms and earthworms (Sharma and Garg 2017). The final vermicompost contained a rich amount of essential macronutrients, such as N (E1-1.24%), P (E0-4.33%), K (E0-7.43%), Ca (E3-34.48%), and Mg (E5-1.20%). Nayak et al. (2013) reported that many essential plant-based micronutrients increase during the vermicomposting process. Apart from this, the final substrate materials contain a low level of toxic heavy metals. Lee (1985) indicated that an enormous amount of heavy metal ions could bio-accumulate in the earthworm species' internal tissue (e.g. chlorogogen tissue). The body of the earthworm contains metal-binding protein like metallothionein that effectively binds with several heavy metal ions, resulting in a minimum amount of metals found in the earthworm-treated substrate (Cherian and Nordberg 1983; Hait and Tare 2011).

FT-IR

Maturity/stability assessment was done through the FT-IR spectroscopy technique. Based on FT-IR spectroscopic techniques, the normal distribution of absorption bands in the vermicomposting samples was observed. Similar results were documented by Fleming and Williams (2019). The FT-IR spectrum of vermicomposting samples is depicted in Figure 3.

The notable peaks were recorded in E5 (3774 cm^{-1}) and E6 (3848 cm^{-1}), which strongly contain the N-H variety of amide compounds, and it was also confirmed by Purandaradas et al. (2018). A medium sharp peak indicated alcohol and phenol groups, as Kumar et al. (2013) documented. The amount of lower peak strength for CH_3, CH_2, and CH at 2920-2991cm-1 in vermicompost samples suggested a decline in the level of alkane compounds (Mothé et al., 2018). The suggestion of a diminishing pattern of aliphatic C-H stretching at 2936-2958 cm^{-1} supported the degradation of lipids and carbohydrates from substrate materials (Bhat et al., 2017). C=O and S-H stretching vibration of carbonyl and Mercaptans suggested the presence of two distinct weak stretches at 2425-2426 cm^{-1} and 2519 cm^{-1}. The peak at 1517 cm^{-1} correlated to the characteristics of the amine groups (Amide-II) from waste materials (Mothé et al. 2018). Various heights at 1417-1422 cm^{-1} might be due to the presence of carboxylic acid. The peak of 1460-1420 cm-1 corresponded to the vibration of lignin in the area, and 1100 cm-1 reflected the cellulose and hemicellulose C-O stretch (Mothé and De Miranda 2009). The broad peaks of 1041-1093 cm^{-1} were associated with anhydride, primary alcohol, and secondary alcohol stretching of CO-O-CO, S = O C-O. Furthermore, peaks of 1047-1091 cm^{-1} relatively humic acid content in compost and vermicompost (Kumar et al. 2015). The peak at 874 cm^{-1} is known to be the esters of the S-OR stretching group. The S-S bonds were absorbed adequately at the height of around 537–599 cm^{-1}, as confirmed by Wojciechowska et al. (1999) and Vasconcelos et al. (2008). Nitrogen-containing compounds in their infrared spectrum improved very distinctive absorption lines. C-N-C deformation was caused by mild to heavy bands at 580-418 cm-1 (Rastogi 1991).

During the biodegradation process, a substantial amount of cysteine in the chicken feathers produced a considerable NH_3. The feather bi-sulfide cysteine was broken into a stable secondary keratin structure (Wang et al. 2000). Earthworms' combined microbial and digestive enzymes efficiently broke down the complex feather waste materials and produced the nutrient-rich vermicompost (Zhang et al. 2000; Aira et al. 2007).

Conclusion

Our results strongly suggest that *Eudrilus eugeniae* and fortification with beneficial microbes of Panchagavya convert the chicken feather waste materials into nutrient-rich vermicompost. Among the various amendment combinations, 0.050:1 ratio (E1) of chicken feather waste to cow dung provides a significant result in compost maturity and nutrient status and reduces environmental contamination from chicken feather waste materials. Therefore, this combination (E1) can be used for large-scale vermistabilization of chicken feather waste materials to enhance soil fertility and agricultural plant production.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

MA gave the idea and prepared the outlines and draft of the manuscript. DSK, RJ, AY, and RT designed the figures along with comprehensive tables along with critical editing and reviewing of the whole manuscript. All the authors have read and approved the final version.

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Tables

Table 1 Pre-decomposed panchagavya fortified Chicken feather waste in different concentration ratios

Treatments	Substances (g/Kg)	Ratio
E0	CFW : CD	0.000 : 1
E1	CFW : CD	0.050 : 1
E2	CFW : CD	0.100 : 1
E3	CFW : CD	0.200 : 1
E4	CFW : CD	0.300 : 1
E5	CFW : CD	0.400 : 1
E6	CFW : CD	0.500 : 1

CFW - Chicken feathers waste; CD - Cow Dung.

Table 2 Physico-chemical properties of pre-decomposed chicken feather waste

Days	T1			T2			T3		
	Temp	Moisture	pH	Temp	Moisture	pH	Temp	Moisture	pH
10	25.87±0.45^{b}	85.65±0.61^{b}	7.69±0.25^{b}	25.87±0.68^{c}	83.50±0.89^{b}	8.61±0.12^{ab}	25.00±0.36^{e}	75.78±0.77^{a}	6.51±0.21^{a}
20	25.77±0.61^{b}	88.43±0.82^{a}	8.14±0.20^{a}	27.83±0.50^{bc}	86.36±1.10^{a}	9.05±0.36^{a}	27.80±0.70^{d}	70.26±1.64^{b}	6.12±0.08^{b}
30	26.13±0.80^{b}	82.50±0.93^{c}	7.93±0.10^{ab}	27.40±0.50^{bc}	81.22±0.88^{c}	8.62±0.29^{ab}	31.70±1.01^{c}	67.05±1.67^{c}	6.01±0.11^{b}
40	26.87±0.60^{b}	79.40±0.77^{e}	8.07±0.05^{ab}	27.33±1.16^{bc}	81.48±1.31^{c}	8.33±0.16^{b}	39.63±1.25^{a}	62.09±1.53^{d}	6.00±0.19^{b}
50	28.37±0.81^{a}	80.75±0.52^{d}	8.14±0.42^{a}	28.23±1.06^{b}	79.22±1.02^{d}	8.57±0.41^{ab}	35.40±1.41^{b}	58.87±0.49^{e}	6.13±0.07^{b}
60	29.47±0.96^{a}	76.21±0.80^{f}	7.89±0.15^{ab}	30.23±1.20^{a}	73.45±1.16^{e}	8.76±0.26^{ab}	32.07±1.55^{c}	58.97±1.57^{e}	6.16±0.07^{b}
F Value	13.090	101.800	1.812	5.718	50.129	2.073	64.618	73.966	5.976
Sig	0.000	0.000	0.185	0.006	0.000	0.140	0.000	0.000	0.005

T1- Chicken feather waste with fresh cow dung; T2- Chicken feather waste with dry cow dung; T3- Chicken feather waste with Panchagavya.

Table 3 The average mortality of *Eudrilus eugeniae* in different ratios of panchagavya fortified chicken feather vermicompost

	Average Mortality Rate / Days									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
E0	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
E1	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
E2	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.67 ± 0.67^{c}	4.00 ± 0.58^{cd}	8.33 ± 1.20^{c}	13.67 ± 2.03^{d}	20.33 ± 2.19^{b}	23.00 ± 1.15^{a}	24.67 ± 0.33^{a}
E3	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.67 ± 0.67^{b}	3.67 ± 2.33^{bc}	7.67 ± 2.73^{bc}	12.00 ± 2.31^{bc}	17.33 ± 2.03^{cd}	20.33 ± 1.76^{b}	23.00 ± 2.00^{a}	25.00 ± 0.00^{a}
E4	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	1.67 ± 1.67^{b}	7.67 ± 0.88^{ab}	12.33 ± 1.76^{ab}	17.67 ± 1.33^{a}	21.67 ± 1.33^{ab}	23.67 ± 0.88^{ab}	25.00 ± 0.00^{a}	25.00 ± 0.00^{a}
E5	1.00 ± 0.58^{ab}	2.33 ± 0.67^{b}	5.00 ± 0.58^{a}	11.33 ± 1.86^{a}	14.33 ± 2.60^{a}	18.67 ± 2.19^{a}	22.33 ± 1.33^{a}	24.67 ± 0.33^{a}	25.00 ± 0.00^{a}	25.00 ± 0.00^{a}
E6	1.67 ± 0.88^{a}	3.00 ± 1.15^{a}	4.67 ± 1.45^{a}	7.67 ± 1.45^{ab}	11.33 ± 2.03^{ab}	15.00 ± 1.00^{ab}	18.00 ± 0.58^{bc}	20.67 ± 0.88^{b}	24.00 ± 1.00^{a}	25.00 ± 0.00^{a}
F	2.90	6.81	6.05	11.70	11.16	29.73	52.39	86.00	152.31	9326.00
Sig	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4 Physico-chemical parameters in different ratios of panchagavya fortified chicken feather vermicompost

Experiments	pH	Moisture (%)	Organic Matter (%)	Organic Carbon (%)	Ash (%)
E0	6.67±0.14^{c}	56.89±4.75^{d}	40.45±1.68^{bc}	23.52±0.97^{bc}	57.67±1.75^{ab}
E1	7.42±0.16^{ab}	67.83±2.76^{bc}	44.52±4.00^{a}	25.89±2.33^{ab}	53.40±4.19^{bc}
E2	7.49±0.16^{a}	68.51±1.12^{b}	43.76±1.18^{ab}	25.31±0.71^{ab}	54.21±2.47^{bc}
E3	7.18±0.05^{b}	71.34±1.14^{b}	47.45±2.49^{a}	26.47±1.25^{a}	51.48±1.78^{c}
E4	6.67±0.21^{c}	63.91±0.68^{c}	45.46±0.99^{a}	25.76±1.20^{ab}	54.27±1.97^{bc}
E5	5.74±0.08^{e}	75.77±0.73^{a}	43.71±1.64^{ab}	24.50±1.16^{abc}	56.46±0.88^{ab}
E6	6.30±0.23^{d}	68.07±2.52^{bc}	37.90±1.16^{c}	22.53±0.80^{c}	59.25±1.40^{a}
F Value	47.448	18.348	6.800	3.548	4.124
Sig	0.000	0.000	0.002	0.024	0.014

Table 5 Elemental analysis using energy dispersive spectroscopy of panchagavya fortified chicken feather vermicompost

	E0		E1		E2		E3		E4		E5		E6	
	Wet. %	At. %	Wet. %	At. %	Wet. %	At. %	Wet. %	At. %	Wet. %	At. %	Wet. %	At. %	Wet. %	At. %
Ca	18.69	12.48	55.64	39.18	7.10	3.72	13.45	6.04	30.12	15.75	5.69	2.93	12.79	5.91
C	9.58	21.34	10.74	25.25	24.38	42.62	34.48	51.63	25.28	44.12	13.34	22.97	27.94	43.06
Si	33.64	32.05	8.89	8.93	46.54	34.80	3.31	2.12	4.69	3.50	36.95	27.21	14.87	9.80
O	6.67	11.16	7.86	13.86	9.54	12.52	27.87	31.33	17.63	23.10	30.46	39.38	27.32	31.61
K	7.43	5.09	4.42	3.19	3.34	1.80	4.80	2.21	6.02	3.23	6.94	3.67	2.78	1.32
Cl	10.67	8.06	2.74	2.18	2.13	1.26	4.96	2.52	7.14	4.22	1.59	0.93	2.47	1.29
Mo	-	-	-	-	-	-	5.70	1.07	-	-	-	-	-	-
Fe	3.13	1.50	6.52	3.30	5.57	2.10	0.66	0.21	2.79	1.05	2.19	0.81	2.94	0.98
P	4.33	3.74	0.55	0.50	-	-	2.93	1.70	1.13	0.76	0.97	0.65	1.95	1.17
Na	-	-	-	-	0.39	0.36	-	-	1.03	0.94	-	-	0.68	0.54
Al	-	-	-	-	0.36	0.28	-	-	-	-	-	-	-	-
Mg	-	-	-	-	0.64	0.55	1.10	0.81	0.92	0.79	1.20	1.02	4.42	3.37
N	-	-	1.24	2.51	-	-	-	-	0.60	0.89	-	-	-	-
Ti	-	-	-	-	-	-	0.27	0.10	-	-	-	-	-	-
S	4.94	4.13	1.08	0.95	-	-	0.46	0.26	-	-	0.60	0.39	1.39	0.80
Mn	0.34	0.16	0.33	0.17	-	-	-	-	0.36	0.14	-	-	0.29	0.10
Cr	0.58	0.30	-	-	-	-	-	-	-	-	-	-	0.16	0.06
Co	-	-	-	-	-	-	-	-	-	-	0.08	0.03	-	-

Figures

Figure 1

Pre-decomposition of chicken feather waste materials in different treatments. T1- chicken feather waste with fresh cow dung; T2 - Chicken feather waste with dry cow dung; T3 -Chicken feather waste with Panchagavya.

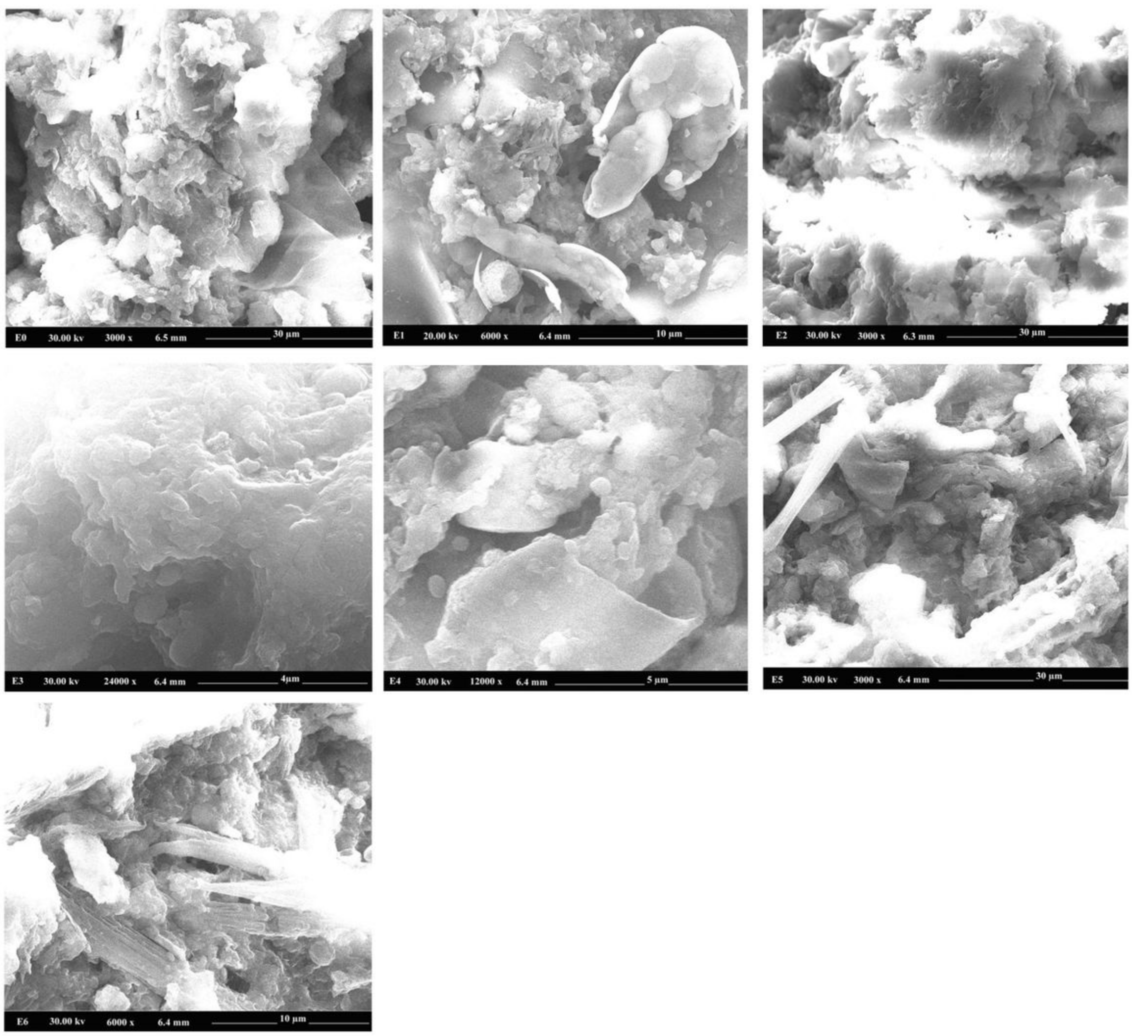

Figure 2

SEM micrographs indicate the morphological structures of panchagavya fortified chicken feather during vermicomposting (E0-E6) process.

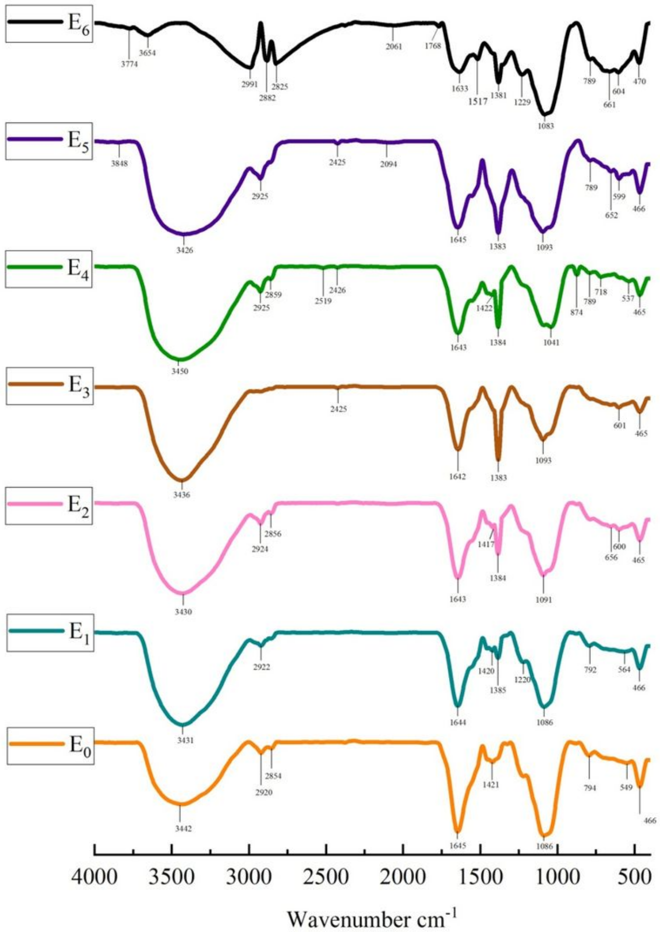

Figure 3

FT-IR analysis of panchagavya fortified chicken feather vermicompost at different ratios.