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Sustainable Management of Different Types of Waste by Vermicomposting Technology

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Abstract The research sought to efficiently manage the garden and paper waste generated in educational institution via the use of the vermicomposting technique. The process consisted of many phases, including the creation of a vermicompost facility, the introduction of compost earthworms (Eisenia foetida) and the production of nutrient-rich vermicompost from garden and paper waste. The study was carried out at Sanatan Dharma College, Ambala Cantt., Haryana. Garden trash and paper waste were produced using the waste generation rates (WG) methodology, which was then processed using the vermicomposting method to create nutrient rich vermicompost that could be supplied to plants as it improved the quality of the soil and contained minerals that plants require.The findings showed that the temperature ranged from 0-35 °C for both types of trash (garden waste and paper waste), the humidity ranged from 56% to 59% and the pH varied from 7.8 to 9.0 before stabilizing to almost neutral on the 60th day. The chemical analysis verified the recovered vermicompost's good nutritional quality and proved that it included all the necessary macro and micronutrients.

Keywords: *Eisenia foetida, Garden waste, Paper waste, Vermicomposting*

1. Introduction

Solid Waste generation has escalated in recent decades due to rapid urbanization, industrialization and changing consumption patterns [1]. Waste management has emerged as a critical global challenge with growing concerns over environmental pollution, resource depletion and climate change. Efficient waste management is essential for mitigating environmental pollution and promoting ecological health. However the complex nature of waste streams and the diversity of waste management practices present challenges in maintaining a healthy ecology [2].Educational institutions are no exceptions as they also generate enormous amounts of solid waste, presenting unique challenges for waste management and environmental sustainability. Biodegradable solid waste including garden waste, canteen waste and paper waste is a significant component of the waste stream generated on college campuses. Sanatan Dharma College, located in Ambala Cantt., Haryana has recognized the importance of addressing waste management issues and adopted vermicomposting to divert organic waste from landfills and produced nutrient rich compost. This method was implemented to pilot the environment conservation, student learning and research endeavours.

Vermicomposting is a composting method that utilizes worms to decompose organic materials into nutrient-rich compost. The worms consume the organic waste materials, such as fruit and vegetable scraps, coffee grounds, eggshells and garden waste and convert them into compost through their digestive process. The end product, known as vermicompost or worm castings, is rich in nutrients and beneficial microorganisms, making it an excellent natural fertilizer and soil conditioner for plants.

Due to its sustainability, the vermicomposting has been acknowledged as a potential approach to handle variety of waste. This environmentally friendly procedure takes a very short time to complete and is quite productive as well as cost-effective [3]. Several earthworm species have been reported for their effective use in vermicomposting, including Eisenia foetida, Eisenia andrei, Eudrilus eugeniae, and Perionyx excavatus. Most commonly used species in vermicomposting and vermiculture worldwide are Eisenia andrei and Eisenia foetida. The earthworm's ability to successfully vermicompost may be mostly attributed to its internal processes of aeration, mixing, grinding, fragmentation, enzymatic digestion and microbial breakdown [4,5]. In addition to providing soil organic carbon and NPK, vermicompost also contains hormones and enzymes that promote plant growth [6]. Comparing vermicompost to ordinary compost, it is thought that pathogens are less prevalent and it is more nutrient rich [7]. Therefore, the main aim of this study was sustainable management of the garden and paper waste generated on the campus by using vermicomposting technology.

Objectives

- Determine the effectiveness of vermicomposting process in handling paper and garden waste by measuring the amount and weight of waste materials reduced over certain time periods.
- To demonstrate the potential of vermicompost as a nutrient-rich organic fertilizer.

2. Methodology

2.1. Materials

The weighing scale used for the trash measurement had a maximum capacity of 120 kg. In addition, a 50-liter aluminum container with a blank weight of 2.5 kg was used to collect and measure the trash. Personal safety precautions included use of facemasks, gum boots and gloves available, along with forks and shovels to load and arrange the trash. The colour coded dustbins were placed at different areas in the college campus for segregation of waste at source.

2.2. Study area

The whole amount of garden trash generated on the Sanatan Dharma College, Ambala Cantt campus was determined by adding up the amount of garden garbage generated from every nook and corner of the campus, which includes the grounds and gardens.

2.3. Garden waste collection

Collection was done in a way that it was taken straight from the property as separate green waste [8, 9, 10]. The collection of green garden trash includes a variety of plant debris, including removed complete plants or plant parts, as well as twigs, branches, blossoms, bark, leaves, hedge cuttings, grass clippings, and other plant detritus.An extensive examination of composting as a means of reusing garden waste has been conducted. Vermicomposting is suggested as a technique by the research [11, 12]. The fact that garden waste generation may vary significantly owing to cyclical and seasonal factors further complicates the process of quantifying the amount produced [13].

2.4. Paper waste collection via dustbins

Paper waste stemming from administrative operations, academic activities and student usage contributes to the overall waste stream on campus. The strategic installation of several receptacles at different places such as social clubs, canteens, offices, labs, libraries and common rooms was used to collect paper trash.

2.5. Waste segregation and measurement

Measuring the weight (Wb) of a blank bin using a weighing scale. The gross weight (WT) of the waste and the bin container were ascertained by filling the bin with sample garbage at the same time and shaking it often to avoid the creation of needless empty spaces. Volume of the trash can measure (VW), finding out how long (ts) the trash was kept and how many people (p) were engaged in producing the waste are the two main goals. Throughout the course of the study, the methodology was used to quantify waste samples from many waste sources and on multiple sampling days.

The WG (waste generation rates) were calculated using the equation:

$$WG= (WT-Wb)\ (kg)\ p/(pe)\times ts\ (d)\ (kg\ pe^{-1}\ d^{-1})$$

2.5.1 Vermicomposting Units

Development of the vermicomposting tanks

7 x 3 x 3 cubic feet (length breadth height) vermicompost tanks were built in a shaded area [14,15]. Earthworms were grown in specially planned and built 100x60x30 cm^3 containers. To optimize the efficiency of water drainage, the concrete modules were equipped with drainage holes with a size of 2 by 2 cm^2. The roof of the tanks was built from zinc sheets, which were insulated to provide a cool environment. Air circulation is maximized by the wire mesh walls utilized in the building of the vermicompost tanks.

2.5.2 Arrangement of culture bed

The base layer served as the foundation of the tankand was made level and sturdy to support the weight of the tank and its contents. Proper drainage is essential in this layer to prevent waterlogging, especially in vermicomposting tanks where excess moisture can be detrimental to the worms. Next to it, an insulation layer may be added to the base to help maintain optimal temperatures for composting, particularly during the winter months. This layer can consist of materials like foam board or styrofoam, which help retain heat generated by the composting process. Upper to it is composting layer, this is where the actual composting process takes place. For vermicomposting, this layer contains a mixture of organic waste materials that can be garden waste or paper waste, bedding materials (like shredded newspaper or cardboard), and, of course, the worms. To this strata were introduced earthworms, *Eisenia foetida*. Dried or newly fallen leaves were arranged in clusters all over the ground. A layer of dried grass clippings or paper waste, as thick as 10 cm, was covering the earth. The whole setup was covered by jute bags to protect the earthworms from sunshine and bird predators. The vermicompost was turned once a week until it was ready for collection and water was added twice a week to maintain it appropriately moist.

2.6. Chemical analysis

Vermicompost sampling was done at certain intervals, namely between 0 and 100 days. When garbage is combined with cow dung at the first stage of decomposition, it is referred to as "0 day". The pH was tested using a digital pH meter, while the electrical conductivity was obtained using a conductivity meter. The “Walkley and Black rapid titration” methodology was employed to measure the total organic carbon [16], whereas the micro Kjeldahl methodwas used to calculate the total Kjeldahl nitrogen[17]. The total potassium level was assessed using the Flame emission approach, whereas the accessible phosphorus was assessed using the Bray and Krutz method. For every sample, the analyses were done in triplicate.

2.7. Statistical analysis

The SPSS (Version 25) software was used to perform the statistical tests. The mean and standard deviation were used to describe all continuous values, whereas numbers and percentages were used to represent categorical data. Descriptive statistics were used to determine the frequencies and proportions.

3. Result & Discussion

3.1 Chemical Properties during Vermicomposting

- **pH**

  Analysis of variance (ANOVA) revealed significant differences ($P<0.05$) between the pH change in the various substrates on the first and last sample days. The figure 1 shows pH levels during a 60-day vermicomposting process for garden waste (GW) and paper waste (PW). Initially, GW has a pH of 7.1 and PW 7.2. GW's pH gradually increases to 8.9, with some fluctuations. PW rises sharply to 9.0 by day 10, then decreases to 7.5 by day 30, and slightly increases to 7.8 by day 60. Overall, GW becomes more alkaline over time, while PW peaks early and then stabilize at a lower pH. This indicates that GW and PW exhibit different pH changes during vermicomposting, with GW consistently rising and PW stabilizing after an initial peak. [18]. A decrease in pH has been reported by several authors throughout the vermicomposting process, with the major explanation being the release of organic acids during the bioconversion process and the creation of CO_2 during the breakdown of organic molecules [19]. There was apH change during the vermicomposting of garden waste towards a comparatively alkaline environment. By secreting intestinal calcium and ammonia, which neutralize the carboxylic and phenolic groups of humic acids created throughout the process, earthworms keep the pH in the neutral range during vermicomposting [20].

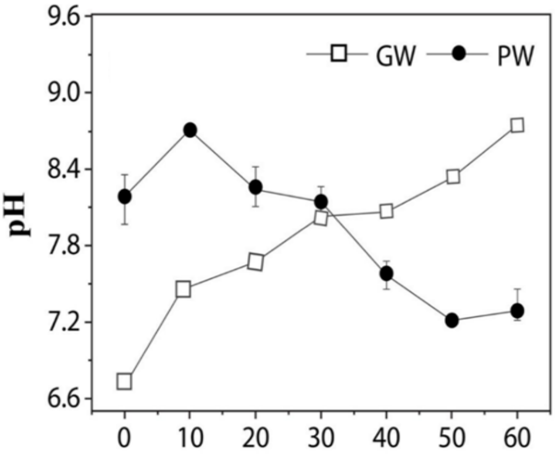


Fig 1. pH

- **Moisture Content**

  The garden trash and paper waste were found to have moisture contents of 56% and 59%, respectively. In organic waste treatment, 85% of the moisture content was ideal for the development of earthworms *(E. foetida, E. eugeniae, and P. excavatus).* The ideal moisture content accelerates the rate of mineralization and breakdown [21, 22]. Moisture levels have been linked to earthworm growth rates. According to reports, *E. fetida* thrives in a humidity range of 60% to 90%, and the experiment's moisture content percentage falls within this range [23]. Low moisture conditions may also delay sexual development; it was shown that earthworms of the same age produced clitella at various periods under different moisture levels. In another investigation it was observed that the moisture level of 60-70% was confirmed to have maximum microbial activity, whereas 50% moisture content was the least required for fast growth in microbial activity [24,25].

- **Total Organic Carbon (TOC)**

  The figure 2 illustrates the changes in Total Organic Carbon (TOC) during vermicomposting for garden waste (GW) and paper waste (PW) over 60 days. Initially, GW starts with a TOC of about 46.5%, while PW begins at approximately 45%. Over time, both GW and PW show a decreasing trend in TOC. GW's TOC decreases slightly but remains relatively stable around 45-46%, with minor fluctuations. In contrast, PW's TOC decreases more significantly from 45% to around 42% by day 60. This indicates that during vermicomposting, the TOC content in PW decreases more substantially compared to GW, suggesting a higher rate of organic matter decomposition in paper waste.The physical characteristics and chemical makeup of certain materials have a direct impact on how quickly earthworms decompose organic waste[26]. Vermicomposting of industrial or municipal wastes has also been shown to reduce TOC into CO_2[27]. According to a number of studies, earthworms alter the parameters of the feed mixture, which increases the amount of carbon that is lost from it as CO_2 via microbial respiration [28-30].

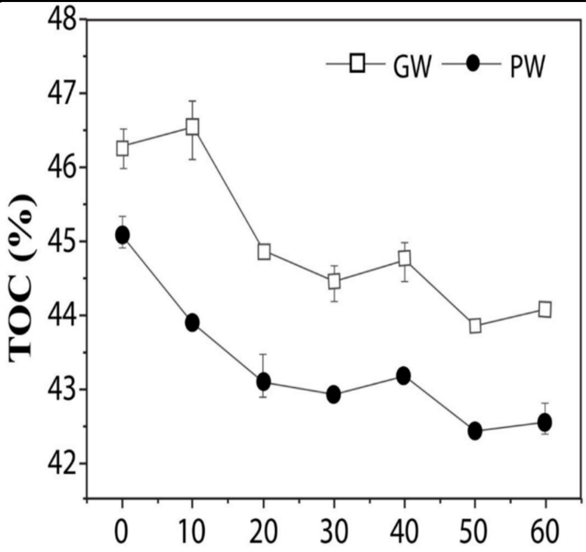


Fig 2. Total Organic Carbon (TOC)

- **Total Nitrogen (TN)**

The figure 3 displays the Total Nitrogen (TN) levels during vermicomposting for garden waste (GW) and paper waste (PW) over a 60-day period. Initially, GW starts with a TN of about 12 g/kg, while PW begins at approximately 18 g/kg. Throughout the vermicomposting process, TN levels in GW show a steady increase, reaching around 20 g/kg by day 60. PW, on the other hand, starts higher and increases more gradually, peaking at about 24 g/kg around day 40, and then stabilizing slightly below this peak towards day 60, in contrast to this TN rose between 1.2 and 2.9-fold during the vermicomposting of rice straw and paper trash[31]. An increase in the end product's nitrogen content in the form of mucus, nitrogenous excretory chemicals, growth-stimulating hormonesand earthworm enzymes have also been reported [32]. It has also been discovered in another research that the amount of decomposition and the starting N content of the trash determine the final N content of the compost [33,34].

This indicates that while both types of waste see an increase in TN during vermicomposting, PW maintains a consistently higher TN level compared to GW. The significant rise in TN for GW suggests that nitrogen accumulation is more pronounced in garden waste over time, whereas PW shows an early peak and then stabilizes.

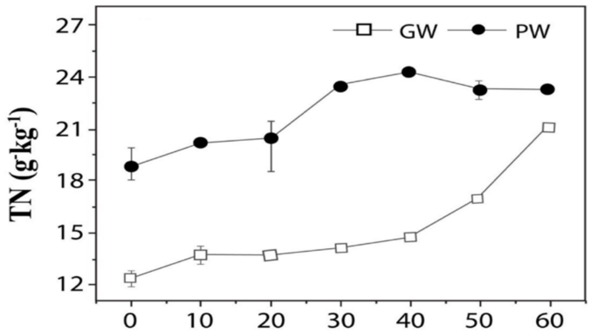


Fig 3. Total Nitrogen (TN)

- **Carbon and Nitrogen Ratio (C/N Ratio)**

It serves as a key indicator influencing vermicomposting by reflecting the degree of organic waste degradation, making the C/N ratio a critical factor in this process. A lower ratio indicates a greater level of degradation [35]. For garden waste and paper waste, the figure 4 illustrates the Carbon to Nitrogen (C/N) ratio during vermicompostingover a 60-day period. Initially, GW starts with a C/N ratio of around 37, while PW begins at approximately 23. Over the 60 days, GW shows a consistent decrease in the C/N ratio, dropping to about 25 by day 60. PW, on the other hand, starts with a lower C/N ratio and decreases more gradually, stabilizing around 18-20 towards the end of the period. This suggests that GW undergoes a more pronounced reduction in carbon relative to nitrogen over time, whereas PW maintains a more balanced C/N ratio.This was in line with findings that during the vermicomposting of wastepaper, there was a greater loss of carbon and a corresponding rise in nitrogen, resulting in a fall in the C/N [36].Research also showed that throughout the vermicomposting process, the C:N ratio—one of the most often used indicators of compost maturation—sharply dropped [37-38]. Findings from many investigations also showed that the earthworms' acceleration of humification during vermicomposting results in a drop in the C/N ratio [39,4

Fig 4. Carbon and Nitrogen Ratio (C/N Ratio)

- **Total Phosphorous and Total Potassium (TP & TK)**

In all vermicomposting units, the total phosphorus content was considerably ($p < 0.05$) greater than the original values determined by varying the composting interval time. Fig 5& 6 illustrates how the percentage of TP and TK in paper trash and garden waste rose over time. During vermicomposting, both garden waste (GW) and paper waste (PW) exhibit increases in Total Phosphorus (TP) and Total Potassium (TK) levels over a 60-day period. For TP, GW starts at around 1.5 g/kg and steadily rises to approximately 4.5 g/kg by day 60. In contrast, PW begins at 3 g/kg, increases rapidly to a peak of 6 g/kg by day 20, and then stabilizes around 5 g/kg towards day 60. This suggests a quicker phosphorus accumulation in PW compared to GW, which shows a gradual increase.Regarding TK, GW starts at about 5 g/kg and steadily increases to a peak of around 8 g/kg by day 40, followed by a slight decrease and stabilization at 7 g/kg by day 60. PW, however, begins at 7 g/kg and experiences a more significant increase, peaking at approximately 13 g/kg by day 40 before decreasing to around 10 g/kg by day 60. These observations indicate that while both waste types see an increase in nutrient levels during vermicomposting, PW generally reaches higher levels more quickly and then stabilizes, whereas GW shows a more gradual and sustained increase over time. Previous research indicates that the factors that contribute to TP rising include raw materials, processing time, worm quality, worms and test circumstances [41,42]. The increase in total phosphorus during vermicomposting is most likely caused by the mineralization and mobilization of phosphorus because of the earthworms' fecal phosphatase and bacterial activity [43, 44]. The results of present findings were in line with the research done that showed that sewage sludge-derived products had a greater K content [45].

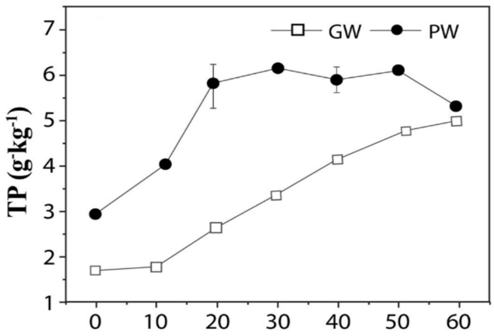
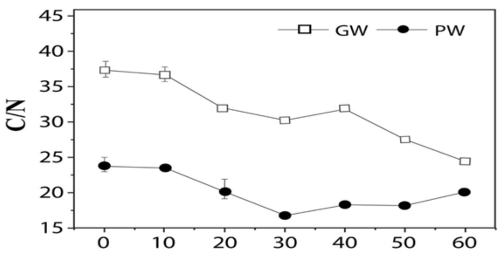


Fig 5. Total Phosphorous (TP)



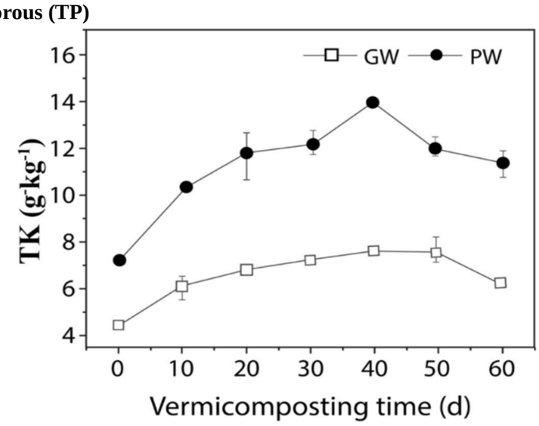


Fig 6. Total Potassium (TK)

4.Conclusion

In conclusion, the implementation of vermicomposting technology for the sustainable management of various types of waste, as evidenced by the case study of Sanatan Dharma College, Ambala Cantt, Haryana, presents a promising solution to the challenges of waste management in educational institutions and beyond. Through the integration of vermiculture techniques, organic waste materials such as paper waste and garden waste are efficiently converted into nutrient-rich compost by earthworms. A vermicompost facility was essential to handling paper and garden waste, converting garbage into an asset for the organization. Compost earthworms, *Eisenia foetida*, were essential to waste transformation. These diligent critters broke down paper and garden trash to create nutrient-rich vermicompost. Waste generation rates (WG) allowed us to quantitatively evaluate our waste management system. Environmental parameters were meticulously monitored throughout the vermicomposting study to ensure success. The stability of pH levels to virtually neutral by the 60th day, temperature ranges of 0-35 °C and humidity levels of 56%–59% showed the robustness and adaptability of waste conversion system. These findings show that vermicomposting may be employed in severalenvironmental conditions, making it suitable for organizations and communities with waste management challenges. Chemical analysis of the harvested vermicompost was vital to our work. The findings showed that vermicomposting works, and that the resulting product is nutrient rich. Vermicompost reduces waste and increases macro and micronutrients, improving soil fertility and sustainable agriculture. This study has proved that vermicomposting technology represents a valuable tool in the pursuit of sustainable development goals, offering a practical, scalable and socially inclusive solution to the challenges of waste management and environmental degradation.

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