Continuous Flow-through Vermireactor for Medium Scale Vermicomposting

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ABSTRACT—*Vermicomposting is increasingly becoming popular as an organic waste management technology whereby earthworms feed on the organic waste to produce vermicasts and vermiwash. Several vermireactors have been used for this process as batch systems. However, there is need to design a continuous flow-through vermireactor which allows the simultaneous addition of the organic waste at the same time harvesting the vermicasts. A 5m X 2m X 1.5m vermireactor was proposed to process an initial feed of 7 500kg. A 10cm thick bedding comprising of office paper, card board paper and Eisenia fetida earthworms stocked at 1kg/m^2 of the vermireactor was used as an initial bedding. The feed bed was 20cm thick and comprised of paper, cow dung, corn pulp and vegetables. The pH, temperature and moisture content in the vermireactor ranged between 5.5-7.5, 19-25°C and 28-52% respectively. 7kg/day of vermicasts were produced given the earthworms produced 75% of their bodyweight as vermicasts per day. The vermireactor was constructed from polyvinyl chloride. Vermicasts containing nitrogen (4.19%), phosphorous (1.15%) and potassium (6.18%) were obtained. The continuous flow-through vermireactor design allowed the production of stable vermicasts and can be used in medium scale vermicomposting.*

Keywords— Earthworms, vermicasts, continuous flow-through vermireactor design

1. INTRODUCTION

Vermicomposting is a bioconversion process whereby organic waste is turned into vermicasts by the action of epigeic earthworms [1-6]. The earthworms eat up the organic waste (feed) and expel it as vermicasts (product), which are dark brown solid particles in nature [6]. These vermicasts are rich in the primary nutrients of a fertilizer i.e. nitrogen (N), phosphorous (P) and potassium (K) [1; 6-7. Furthermore, a leachate called vermiwash is produced alongside the vermicasts and is also rich in NPK [3; 5; 7-9]. Vermicomposting is carried out in different vermireactors such as the windrows, bins and flow-through systems [11]. Vermireactors are biological reactors where earthworms' activities take place. Windrows and bins are batch vermireactors whereby the earthworms, bedding and feed are put initially and the vermicomposting process is allowed to take place until all the vermicasts are obtained at a given retention time [11]. However, the flow-through systems are continuous vermireactors whereby the earthworms are added initially in the bedding, the feed and more bedding are then continually added at certain intervals whilst the vermicasts are also continually harvested [11]. Various organic waste retention times have been used in the vermireactors from 1 month up to 6 months [1; 3-6; 9; 12]. High retention times result in poor quality of the vermicasts as they become unstable [12]. A continuous flow-through reactor would therefore be ideal for stable vermicasts production. No detailed information has been given for continuous flow-through vermicomposting reactors which have the potential to produce quality vermicasts at less labor requirements. Hence, there is need to design a user friendly continuous flow-through vermireactor for vermicomposting. This continuous flow-through vermicomposting reactor can be used by medium scale vermicomposters.

2. MATERIALS AND METHODS

2.1 Materials

The materials that were used in this work are the earthworms and the organic waste.

2.1.1 Earthworms

Eisenia fetida earthworms which are an epigeic species obtained from the Institute vermicomposting project were used [6]. *Eisenia fetida* are surface burrowing earthworms and they bio-convert organic waste to vermicasts efficiently [2; 4; 6; 12]. The earthworms had an average length of 9.56±0.61cm and body weight of 0.97±0.02g.

2.1.2 Organic Waste

Shredded waste paper and cardboard boxes were used as the bedding material. Cow dung obtained from a nearby farm and an organic waste mixture containing waste corn pulp, office paper, card board box and vegetables were used as the organic waste. Cow dung provides with micro-organisms which accelerate the vermicomposting process [6]. The densities of the cow dung, waste corn pulp, office paper, card board box, and vegetables were 550kg/m^3, 673kg/m^3, 1201kg/m^3, 689kg/m^3 and 540kg/m^3 respectively and each organic waste contributed 20% in the total feed.

2.2 Methods

The organic waste and vermicasts pH was measured by a Hanna Instrument, whilst moisture content was measured by an AND moisture analyzer. The temperature was determined by an alcohol thermometer. The detailed measurement methodologies were described earlier [6]. The vermicasts particle sizes were determined through screening. Lastly the nitrogen, phosphorous content in the vermicasts was determined by a *uv-vis* spectrophotometer was the potassium content was determined by a flame atomization spectrophotometer. The total density of the organic waste was determined by multiplying the mass fraction of each waste with its density and adding the weighted densities together i.e. from Section 2.1: 0.2(550kg/m^3) + 0.2(673kg/m^3) + 0.2(1201kg/m^3) + 0.2(689kg/m^3) + 0.2(540kg/m^3) to give a total weighted density of 730.6kg/m^3.

2. 3 The Continuous Flow-through Vermireactor Design

The proposed continuous flow-through vermicomposting reactor was a linear bed which was 5m long, 2m wide and 1.5m deep. This was after the consideration that approximately 600 tons of organic is being produced in Harare, Zimbabwe [6]. These huge sums of organic waste can be converted into the vermicasts hence a big continuous flow-through vermireactor is essential.

3. RESULTS AND DISCUSSION

3.1 Vermicomposting Process Design

The vermicomposting process was designed to ensure optimum processing of the organic waste (Figure 1). The organic waste was first shredded to reduce the particle size. The organic waste was then pre-composted for a week monitoring the pH and moisture content in the feed. Earthworms function well in a pH range of 5.0-9.0, temperatures below 45°C and moisture content of 45-75% [1; 4; 6]. Pre-composting facilitated in making other organisms that can aid the vermicompost process available and also reduction of the organic waste surface area whereby the earthworms will act on. The feed was then introduced into the continuous flow-through vermireactor whereby the vermicomposting process was initiated by adding the earthworms. pH, temperature and moisture content were continually monitored whilst the vermicasts and vermiwash produced were collected at the bottom of the vermireactor for storage (Figure 1).

3.2 Organic Waste Feed Rate into the Continuous Flow-through Vermireactor

The preferred organic waste density to be used for optimum composting is 350-650kg of waste/m^3 of the vermireactor [13]. An optimum organic waste density of 500 kg of waste/m^3 of the vermireactor was used; therefore, an initial organic waste quantity of 7500kg (i.e. 10.27m^3 of organic waste considering a weighted density of 730.6kg/m^3 for the organic waste) was used.

3.3 Earthworms Stocking Density and Substrate Retention Times

Earthworm density refers to the weight of earthworms used/m^2 of the vermireactor. A stocking density of 1kg/m^2 is optimum for use in the vermireactor [6]. Earthworm density is very critical because the earthworms function as a bioreactor inside the continuous flow-through vermireactor themselves [12]. This is because the bioconversion processes of the organic waste take place inside the earthworm gut whereby the organic waste is the input and the vermicasts are expelled into the vermireactor as a product. The organic waste can stay inside the earthworms' gut for a period of 24 hours after ingestion [12]. During this time the organic waste goes through subsequent physical size reduction in the earthworm's gizzard. The organic waste which is the substrate in this case is acted upon by enzymes and micro-organisms in the earthworm gut. Furthermore, the rate of vermicasts produced is depended on the length of the earthworm, the shorter the earthworm, the shorter the residence time inside the earthworm gut. Earthworms ingest 75% of their body weight/day [13]. Therefore it is assumed that more than 7kg of vermicasts was being produced per day given that the earthworms increase in number, weight and size daily.

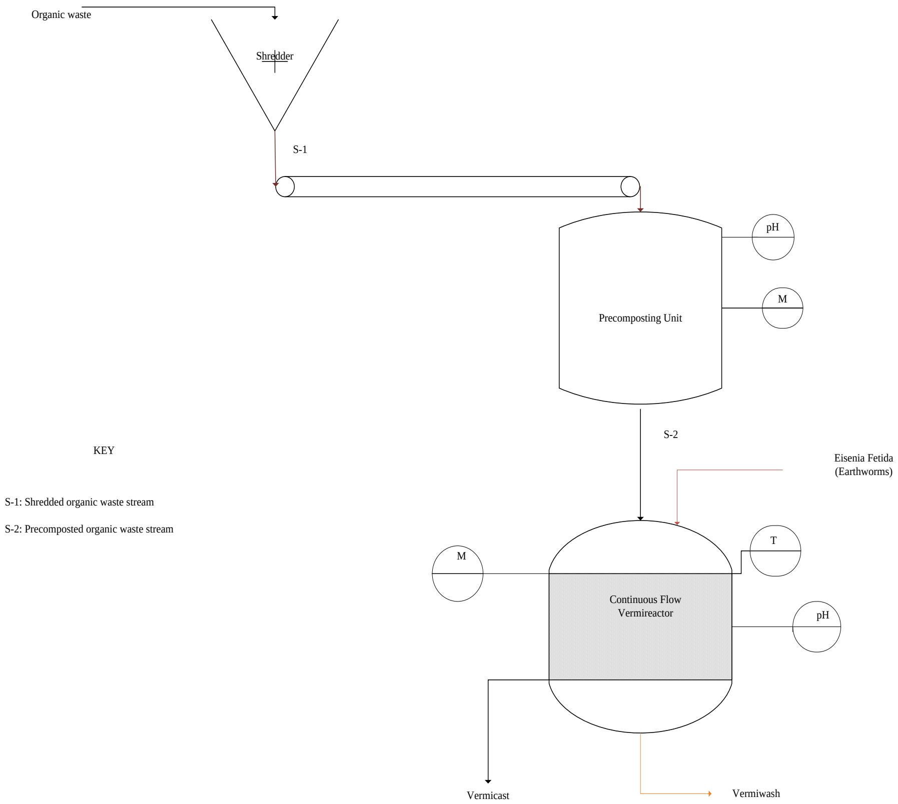

Figure 1: Vermicomposting Process Flow Diagram

3.4 Continuous Flow-through Vermireactor Aeration Facility

Vermicomposting is a non-exothermic reaction hence there were no major changes in the vermireactor temperatures that may require controlling [12]. Instead the movement and burrowing action of the earthworms provided sufficient aeration in the vermireactor. The rate of decomposition of the organic waste was therefore classified as aerobic since there was sufficient movement of air within the vermireactor [12]. Furthermore, earthworms thrive best in aerobic conditions and this earthworm movement ensured there is sufficient oxygen in the vermireactor.

3.5 Continuous Flow-through Vermireactor Design Parameters

The continuous flow-through vermireactor was made up of polyvinyl chloride (PVC). This was chosen as the material of construction due to PVC's high yield strength, mechanical and thermal properties in the event of overloading the organic waste. The continuous flow-through vermireactor was classified as a continuous stirred tank reactor and the diagrammatic presentation is indicated in Figure 2. The presumed continuous stirring was due to the movement and burrowing action of earthworms on the organic waste resulting in uniform mixing. There was therefore no need to include any mechanical agitation in the vermireactor [12]. In the continuous flow-through vermireactor, initial bedding with thickness of 10cm was used. The bedding comprised of shredded office paper and card board box which was put at the bottom of the vermireactor as a means of preventing the organic waste from falling through the mesh. The vermireactor was then fed with the earthworms and feedstock of 20cm thickness. This feed was continuously renewed once every week. Thin layers of bedding were used to allow proper diffusion of air and prohibition of anaerobic conditions. A maximum of 30cm thickness can be used for the bedding [13]. The feed was added when necessary by the means of rollers. The egested vermicasts of about 10-20mm particle diameter were released from the bottom of the vermireactor via a wire mesh (Figure 2). No earthworms left the vermireactor with the vermicasts as they had a tendency to move up the vermireactor due to the attraction from the fresh organic waste. Furthermore, a breaker bar was put on top of the mesh across the vermireactor to break down vermicasts that had caked during vermicomposting by its moving action every time fresh organic waste was added. An air space of 0.15m depth was kept below the screen for proper vermiwash drainage. A leachate collection pipe was installed for vermiwash collection. The collected vermicasts were taken for further screening and storage. A summary of the vermireactor design parameters is given in Table 1.

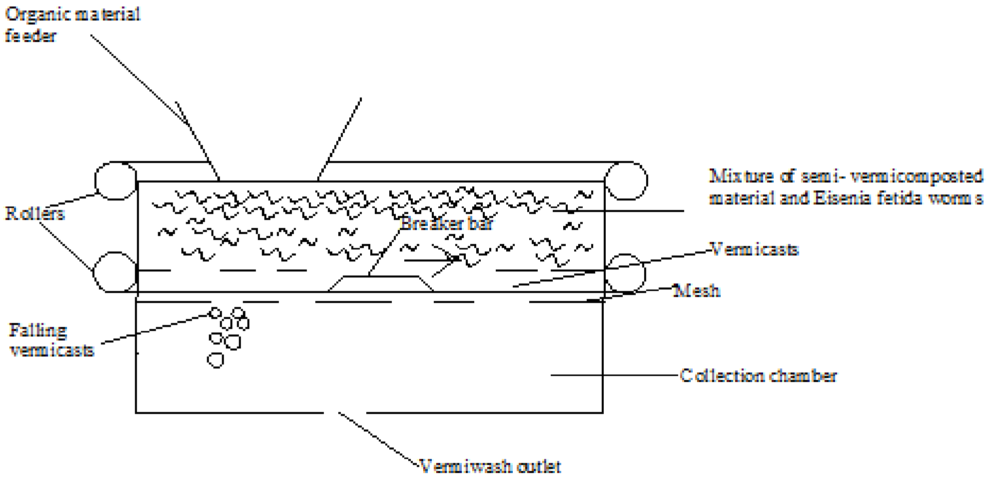

Figure 2: The Continuous Flow-through Vermireactor Mechanism

Table 1: The Continuous Flow-through Vermireactor Design Parameters

Parameter	Property
pH	5.5-7.7
Temperature	19-25◦C
Moisture content	28-52%
Vermireactor dimensions	5.0m X 2.0m X 1.5m
Initial feed	7 500kg
Earthworm stocking density	1kg/m^2 of vermireactor
Bedding material thickness	10cm
Feed material thickness	20cm
Vermireactor material of construction	PVC
Operation mode	Continuous

3.6 Physicochemical Characteristics of the Vermicompost

The vermicasts obtained from the mixed organic waste contained N (4.19%), P (1.15%), and K (6.18%) as the major trace elements. The vermicasts obtained were richer in NPK compared to the typical nutrient analysis found in vermicasts i.e. N (1.5-2.5%), P (1.25-2.25%) and K (1-2%) [13].

4. CONCLUSION

Vermicomposting require less labor intensive equipment for production of the NPK rich vermicasts. A continuous flow-through vermireactor was designed for medium scale vermicomposters. The vermireactor allows the simultaneous addition of the organic waste and collection of vermicasts. The vermicasts obtained were very stable and showed higher NPK compositions compared to the given ranges of vermicasts.

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REFERENCES

1. D. C. Jadia and M. H. Fulekar, "Vermicomposting of vegetable waste: A bio-physicochemical process based on hydro- operating bioreactor ", African Journal of Biotechnology, 7 (20), pp. 3723-3730, 2008.
2. G. Nath, K. Singh and D. K. Singh, "Chemical Analysis of Vermicomposts/Vermiwash of Different Combinations of Animal, Agro and Kitchen Wastes", Australian Journal of Basic Applied Sciences 3 (4), pp. 3671-3676, 2009.
3. M. Gopal, A. Gupta, C. Palaniswami, R. Dhanapal and G. V Thomas, "Coconut leaf vermiwash: a bio-liquid from coconut leaf vermicompost for improving the crop production capacities", Current Science, 98, pp. 1202-1210, 2010.
4. A. W. Zularisam, Z. Siti Zahirah, I. Zakaria, M. M Syukri, A. Anwar and M. Sakinah, "Production of fertilizer from Vermicomposting Process of Municipal Waste", Journal of Applied Sciences, 10 (7), pp. 580-584, 2010.
5. V. Palanichamy, B. Mitra, N. Reddy, M. Katiyar, R. B. Rajkumari, C. Ramalingam and Arangantham, " Utilising Food Waste by Vermicomposting, Extracting Vermiwash, Castings and Increasing Relative Growth of Plants", International Journal of Chemical and Analytical Science, 2 (11), pp.1241-1246, 2011.
6. M. M. Manyuchi, A. Phiri, N. Chirinda, P. Muredzi, J. Govha and T. Sengudzwa, "Vermicomposting of Waste Corn Pulp Blended with Cow Dung Manure using Eisenia Fetida", World Academy of Science, Engineering and Technology, 68, pp. 1306-1309, 2012.
7. A. A. Ansari and K. Sukhraj, "Effect of vermiwash and vermicompost on soil parameters and productivity of okra (abelmoschus esculentus) in Guyana", Pakistan Journal Agriculture Resources, 23, pp. 137-142, 2010.
8. C. Sundaravadivelan, L. Isaiarasu, M. Manimuthu, P. Kumar, T. Kuberan and J. Anburaj, "Impact analysis and confirmative study of physico-chemical, nutritional and biochemical parameters of vermiwash produced from different leaf litters by using two earthworm species", Journal of Agricultural Technology, 7 (5) , pp. 1443-1457, 2011.
9. G. Nath, K. Singh, "Effect of vermiwash of different vermicomposts on the kharif crops", Journal of Central European Agriculture, 13 (2), pp. 379-402, 2012.
10. S. Quaik, A. Embrandiri, P. F. Rupani, R. P. Singh and M. H. Ibrahim, "Effect of vermiwash and vermicompost leachate in hydroponics culture of Indian borage (Plectranthus ambionicus) plantlets", 11th International Annual Symposium on Sustainability Science and Management, pp. 210-214, 2012.
11. G. Munroe, "Manual of On-Farm Vermicomposting and Vermiculture", Organic Agriculture Centre of Canada, pp. 1-56.
12. T. Abbasi, S. Gajalakshmi and S. A. Abbasi, "Towards modelling and design of vermicomposting systems: Mechanisms of composting /vermicomposting and their implications", Indian Journal of Biotechnology, 8, pp. 177-182, 2009.
13. H. Chaoui, "Vermicasting (or Vermicomposting): Processing Organic Wastes through Earthworms", Factsheet, ADGEX 743/537, 2010.