

Viability of Medium-Scale Vermicompost Plant: a Case Study in Kushtia, Bangladesh

Abu Shahadat Md Ibrahim¹, Ashif Mohammad^{2*}, Md Ibrahim Khalil³, S. M Nasif Shams⁴

¹ Colorado School of Mines, USA

²Deputy Station Engineer, Bangladesh Betar

³Institute of Energy, University of Dhaka

⁴Associate Professor, Institute of Energy, University of Dhaka

Corresponding Author: Ashif Mohammad ashif028628@gmail.com

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ABSTRACT

In Bangladesh, vermicomposting has been a popular environmentally friendly composting technique, primarily at small-scale levels. However, few studies have explored the feasibility of medium to large-scale operations. This study establishes a medium-scale vermicompost fertilizer plant in Kushtia, Bangladesh, processing 30 tons of waste monthly to produce 10 tons of fertilizer. Utilizing cow dung from nearby dairy farms and 0.1 million red worms (*Eisenia foetida*), the experiment runs for three cycles of 120 days each without indoor environmental controls. Over a year, the worm population quadruples to over 0.4 million. Lab tests confirm the fertilizer's pH level (7.69) and nutrient ratios (e.g., 1.792% nitrogen, 0.5217% phosphorus, and 1.514% potassium). The paper includes a cost-benefit analysis, suggesting the viability of such medium-scale setups for green farming in rural Bangladesh.

INTRODUCTIONs

In the agricultural landscape of rural Bangladesh, where a significant portion of the population engages in farming activities, the abundance of farm waste, including crop residues and cattle manure, has prompted a pragmatic exploration of sustainable and cost-effective approaches to fertilizer production. This study focuses on assessing the viability of a medium-scale vermicompost plant, with a comprehensive case study conducted in Kushtia, Bangladesh. Biomass, a substantial contributor to Bangladesh's energy supply, presents an opportunity for organic fertilizer production. The study specifically delves into vermicomposting, a composting technique known for its eco-friendly attributes and operational efficiency. Unlike conventional thermophilic composting methods, vermicomposting requires minimal reliance on electricity or enzymes, leading to reduced operational costs and machinery depreciation. The study examines the vermicomposting process's performance indicators, such as worm survival, growth, and fertilizer production rate.

The case study centers on establishing a medium-scale vermicompost fertilizer plant in Mohishkundi village, Thana: Doulatpur, District: Kushtia (Figure 1). With a target production capacity of 10 tons of output fertilizer per month, the research evaluates process efficiency, economic viability, and environmental benefits of vermicomposting. The study aims to provide practical insights into the feasibility and potential impact of medium-scale vermicomposting plants in agricultural settings, contributing valuable information for academic and practical considerations. Through systematic analysis and empirical evidence, the study aims to contribute to the academic discourse on sustainable waste management practices and their application in rural farming contexts. By adopting a measured and objective tone, the research seeks to inform scholarly discussions and contribute substantively to the body of knowledge related to vermicomposting in agricultural landscapes.



Figure.1 Vermicompost plant in Kushtia, Bangladesh

LITERATURE REVIEW

To achieve efficient bioconversion of organic wastes to vermicompost, a series of steps categorized as microbial decomposition, earthworms burrowing and biomass ingestion as well as the maturation phase (that is characterized by the migration of earthworms from the already decomposed wastes to freshly introduced ones) are involved. During the initial phase of decomposition, the microbes present in the waste begin the decomposition process, which is followed simultaneously by active ingestion of biomass waste by earthworms and burrowing through the waste. The activities of earthworms facilitate the distribution of both air, water, and microbes through the entire decomposing waste. Upon ingestion of biomass waste by earthworms, their gut-associated symbionts aid them in the digestion of the ingested materials, followed by the earthworms' excretion of their waste as vermicast. This active phase of the earthworms' activities varies with the earthworm species present, their population density, the type of biomass waste introduced, the presence or absence of toxic substances, and the mass flow rate of important substances such as air, waste, and heat within the reactor. The gut microbes of earthworms equally participate in the decomposition process by producing extracellular enzymes that break down cellulose, hemicellulose, lignin, polypeptide, phenolic compounds, lipids and other organic polymers into their monomeric units.

Most notably, earthworms modify the microbial community, diversity, activities, and population as well as the production of nutrient-rich mucus that serves as nutrients to the microbes. It equally conditions the substrate and environment by stabilizing the pH through its intestinal production of ammonia and calcium, which react with carboxylic or phenolic groups of the produced acids - humic acids. The combined activities of earthworms, waste-associated and earthworm - associated microbes facilitate the vermicomposition of biomass material into high nutrients (N, P, K) containing substances fit for agricultural soil fertilization. Kumar et al. (2017) noticed that following 60 days of vermicomposting of cow dung and wheat straw, the nitrogen content increased from 0.84% in the raw biomass waste to 1.34% in the treated vermicompost, potassium from 0.84% to 1.34%, and phosphorus from 1.27% to 1.83% in the vermicompost.

It is noteworthy to mention at this point that earthworms live in the upper layers about 4-6 inches (10-15 cm) deep in the decomposing waste. Other observed that about 52% of earthworms' biomass and 42% of their population were found inhabiting the youngest upper layers of the decomposing biomass waste in the reactor. Earthworms are aerobic organisms that require molecular oxygen for respiration and metabolism, so they tend to reside in the environment or soil or waste at a depth supporting oxygen diffusion and its availability. They hardly survive in an anaerobic environment and often die off or migrate out in response to oxygen tension. To better adapt to their changing environment and chemotactically respond to nutrient availability, earthworm migration in the reactor is a prerequisite for their survival. It seems plausible to routinely or continuously add a small quantity of fresh biomass waste into the

reactor to reduce heat build-up and prevent the development of anaerobic conditions. This practice will stimulate the upward movement of the earthworm into the freshly added material and away from the already decomposed ones. In fact, these earthworm behavioural patterns have been exploited in the construction and operation of continuous feed-automated vermireactor systems. Its operation involves reciprocal or simultaneous addition of fresh waste and the corresponding removal of vermicompost from the system. The automated system will be discussed in detail in the following sections. For efficient earthworm consumption of the waste, in addition, fresh waste should be added on the surface of the previously decomposing ones in thin layers to prevent the generation of excessive heat. Also, the maintenance of reactor temperature at 15–25° and 70–90% of water in the reactor is necessary for waste processing by the earthworms.

METHODOLOGY

Setting up a Vermicompost factory doesn't require heavy infrastructure or expensive construction materials. In this study, a tin-shaded plant was constructed using bricks and bamboo. Initially, the plant consisted of 16 beds, each capable of processing approximately 10 MT of cow dung per month. These beds measured 1.5 m (5 feet) in length, 0.6 m (2 feet) in height, and 0.9 m (3 feet) in width (with R.C.C slab), with each bed processing around 500 kg of wet cow dung and yielding 150-200 kg of output fertilizer per month. To prevent overheating (temperatures inside the pile can reach 65°C or higher, and worm mortality, the feeding layer thickness was limited to less than 0.3 m (1 foot). Additionally, boundary walls surrounded the entire structure and beds to protect them from birds, predators, and other insects.

Feed Collection

A consistent supply of biomass and organic waste is crucial for the operation of any vermicompost plant. Earthworm populations ideally double every two months under optimal conditions. However, interruptions in the supply of raw materials can impede this geometric growth rate. To ensure an adequate feed supply, villagers were encouraged to store cow dung and sell it to the compost plant. Approximately 40 local households and five dairy farms participated, selling their animal dung at an average price of 1000 BDT/MT. The total cost of raw material collection was approximately 1500 BDT/MT, with an additional 500 BDT/MT allocated for packaging and transportation.

Hatching Earth Worms

Out of the vast array of earthworm species, only a select few have been extensively studied and utilized for organic waste processing. Among the most commonly employed species are *Eisenia foetida* (Red wiggler), *Lumbricus rubellus* (Red worm), *Eisenia Andrei* (Red tiger), *Perionyx excavatus* (Blue worm), *Eudrilus eugeniae* (African nightcrawler), Enchytraeids (White worm), *Dendrobaena veneta*, and *Perionyx hawayana*. This experiment procured 0.1 million *Eisenia foetida* (Red wiggler) worms for waste processing and hatching for 1.5 BDT per worm. Ten beds, each housing 10,000 worms and providing ample feed, were utilized for worm reproduction and hatching.

Process Control Parameters

Three crucial parameters for effective vermicomposting are indoor temperature, bedding condition, and feed pH level.

Indoor Temperature

The optimum temperature range for vermicomposting falls between 15° C to 25° C. Extreme cold or hot conditions hinder worm activity, decreasing reproduction and potential mass exit or death. In Kushtia, where the average annual temperature is 26°C, the worm beds were strategically placed below the surface, capitalizing on the relatively stable temperature of the ground. This design choice eliminated the need for electric fans or chillers to control temperature, reducing operational costs.

Bedding Condition

Bedding is a stable habitat for worms, and maintaining proper moisture content is crucial. Worms breathe through their skin, and dry skin can be fatal. The ideal moisture content range for bedding is 45-60%. Moisture meters were employed to assess and regulate the moisture level in the worm beds. A simple smell test served as an indicator; if the feed exhibited a rotten and wet odor, it signified potential anaerobic conditions, known as protein poisoning. If worms attempted to escape despite sufficient food and clean bedding, aeration of the bedding by turning it, introducing dry paper wastes and newspapers, and complete feed replacement treated with powdered limestone addressed the issue.

Feed pH Level

Worms thrive on neutral pH values and prefer feed with a pH of 6.5-7.5. Fresh vegetable or fruit waste typically falls within the acidic range of 3.2-3.5. To adjust pH, powdered limestone (CaCO_3) can be used, but caution is essential as direct contact can harm and eventually kill worms. Thus, dry limestone should be mixed with water before combining it with the feed. Weekly turning of the bedding aids in controlling feed acidity by enhancing aeration, ultimately improving the overall pH level. As cow dung has a pH range of 7.5-8.3 no additional limestone was utilized. To enhance feed quality, a 15% mix of dry stalks and stems was incorporated into the feed.

RESEARCH RESULT

This study investigates Red wiggler worms' daily consumption patterns and reproductive capabilities in vermicomposting, focusing on producing nitrogen, phosphorous, and potassium-rich castings.

Theoretical Estimation

Each worm, weighing approximately 0.5 mg, can process 75% of its body weight daily producing 50% stool or compost fertilizer. In the initial cycle, each bed, hosting 10,000 worms, collectively weighing 5 kg, processes 3.75 kilograms of waste daily per bed, leading to a total daily production capacity of 25 kg fertilizer across ten beds. The experiment sets a 120-day cycle for processing 500 kg of waste/bed. The cumulative theoretical production of the plant after the first cycle is estimated at 3 MT, considering the number of worms remains the same. However, The prolific growth and reproduction rates of red wiggler worms are evident, with a breeding cycle of approximately 30 days and a population doubling every 60 days. After the initial 120-day cycle, the worm population is projected to reach 40,000 per bed, totaling around 0.4 million for the entire plant (Table 1). This calculation lays the foundation for assessing consecutive cycles with an expanding worm population and fertilizer production.

Table.1 Worm Population and Fertilizer Production (Theoretical vs. Practical)

	Initial worm population	After the first cycle worm population	After the first cycle Fertilizer production	After the second cycle worm population	After the second cycle Fertilizer production	After the third cycle worm population	After the third cycle Fertilizer production
Theoretical estimation	0.1 million	0.4 million	3 MT	1.6 million	12 MT	6.4 million	48 MT
Practical findings	0.1 million	0.15 million	2 MT	0.25 million	4 MT	0.4 million	10 MT

Practical Findings

This study investigates disparities between theoretical projections and actual outcomes in a three-cycle vermicomposting experiment, examining the potential impact of uncontrolled indoor environments. Initiated in June 2013, the hatching process involved counting output fertilizer and worm populations. Practical findings deviated significantly from theoretical estimates. After the third cycle, the observed worm population was 0.4 million, contrasting with the expected 6.4 million. Theoretical estimations anticipated fertilizer production of 3 MT, 12 MT, and 48 MT after each cycle, while practical results yielded 2 MT, 4 MT, and 10 MT, respectively. Despite these variations, the factory achieved an operational monthly capacity of approximately 3 MT. This analysis underscores the importance of refining predictive models in vermicomposting, especially when not considering indoor environment controls.

Fertilizer Quality

Table 2 presents the laboratory test report detailing the nutrient content in the output vermicompost fertilizer compared to the ideal standards for both vermicompost and garden compost, as Nagavallema et al. (2004) outlined.

Table.2 Comparative Nutrient Composition of Vermicompost Fertilizer vs. Ideal Standards

Element	Nutrient content (%) in the output sample	Ideal Nutrient content (%) in Vermicompost [15]	Ideal Nutrient content (%) in Garden compost [15]
N (Nitrogen)	1.792	0.51-1.61	0.8
P (Phosphorous)	0.5217	0.19-1.02	0.35
K (Potassium)	1.514	0.15-0.73	0.48
S (Sulphur)	0.135	Not mentioned	Not mentioned
Na (Sodium)	3.5642	0.058-0.158	<0.01
Zn (Zinc)	0.0147	0.0042-0.110	0.0012
Fe (Iron)	0.33092	0.2050-1.3313	1.169
Mn (Manganese)	0.00933	0.0105-0.2038	0.0414
B (Boron)	0.00688	Not mentioned	Not mentioned
Mg (Magnesium)	0.48	0.093-0.568	0.57
Ca (Calcium)	5.5	1.18-7.61	2.27
Cu (Copper)	0.00307	0.0026-0.0048	0.0017

The nutrient composition in the vermicompost sample aligns well with the ideal standards for vermicompost, exhibiting suitable levels of nitrogen (N), phosphorus (P), potassium (K), sulfur (S), zinc (Zn), manganese (Mn), magnesium (Mg), calcium (Ca), and copper (Cu). However, notable deviations are observed in the sodium (Na) and iron (Fe) levels. Despite these variations, the overall nutrient profile suggests the vermicompost fertilizer's potential effectiveness as a soil amendment, suitable for various crops at different stages of growth, including agricultural, horticultural, ornamental, and vegetable cultivation.

DISCUSSION

Establishing a vermicompost plant, which can produce 3 MT to 5 MT of output fertilizer per month and accommodate 1 million earthworms at saturation level, requires a minimum land area of 0.45 acres. The estimated rural land cost is approximately 0.25 million BDT, with an additional 0.2 million BDT allocated for plant construction. Procuring 0.1 million worms costs 0.15 million BDT, calculated at 1.5 BDT per worm. Consequently, the total initial capital investment sums up to 0.60 million BDT. Operational costs include raw material procurement (estimated at 1000 BDT per MT), labor expenses (500 BDT per MT), and packaging marketing costs (500 BDT per MT), resulting in a total production cost of 2000 BDT per MT. Currently, vermicompost fertilizer is retailed at wholesale and retail prices of 12000 BDT per MT and 15000 BDT per MT, respectively. Considering the retail price, a profit margin of 10000 BDT per MT is attainable.

With a sustainable output of 3 MT per month, the simple payback period for the initial investment is calculated as $(0.6 \text{ million BDT}) / (3 \text{ MT} * 10000 \text{ BDT/MT}) = 20$ months. With proper management, the factory can achieve profitability within 2-3 years, providing returns to its investors. However, ensuring a continuous supply of raw materials, such as biomass or animal waste, is crucial for the plant's sustainability. Entrepreneurs should prioritize this aspect during the establishment phase to guarantee long-term success.

CONCLUSIONS AND RECOMMENDATIONS

In summary, this study highlights the feasibility of a medium-scale vermicompost plant in rural Bangladesh, emphasizing operational efficiency and economic viability. Discrepancies between theoretical projections and practical outcomes underscore the need for refined predictive models, especially in uncontrolled environments. The observed nutrient composition aligns with vermicompost standards, suggesting its potential as a soil amendment. The cost-benefit analysis provides insights into initial investment, operational costs, and potential profitability. The research contributes to sustainable waste management discourse, offering practical recommendations for entrepreneurs. Further studies can focus on refining predictive models and optimizing operational parameters for scalability.

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