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Fruit Waste Management through Vermicomposting: The Case of PRAN, Bangladesh

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ABSTRACT
PRAN, situated in Natore, Bangladesh, operates a sizable fruit processing facility. This facility processes approximately two hundred seasonal foods and fruit varieties, generating substantial organic waste. The overarching goal is to establish an organic food chain for both the national and international markets, thereby contributing to the mitigation of Bangladesh's emerging energy and fertilizer crisis. The vermicomposting method was employed, and the experiment was conducted on a miniature scale over 90 days. A dedicated setup was constructed to yield three metric tons of monthly fertilizer. Upon completion of the experiment, the output fertilizer underwent rigorous testing in the laboratory. The results indicated that the component ratios were well-suited for application in agricultural lands. This research marks a significant step towards sustainable waste management and the development of a valuable resource for the agricultural sector in the region.

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INTRODUCTION

Bangladesh's food and fruit processing sector, including the prominent Pran Natore factory, faces significant challenges in managing large quantities of organic waste generated during production. Specifically, the factory's pulping unit annually produces 15000 metric tons of mango seed and skins, posing a considerable disposal burden. Currently, these wastes are deposited in nearby ponds, presenting environmental and economic concerns. However, the factory intends to transition to more sustainable waste management practices, particularly by converting these wastes into organic or compost fertilizer.

This study focuses on identifying an effective composting method for the Pran Natore factory, explicitly targeting the utilization of mango seeds and skins. Vermicomposting stands out among various organic waste decomposition techniques as a promising solution. This eco-biotechnical process, involving earthworms and mesophilic microorganisms while omitting the thermophilic stage (R.A. Whiston, 1988), enhances microbial activity (J.K. Syers, 1979). Earthworms play a crucial role in converting wastes into a homogenized, nutrient-rich, and stable end product (Eastman, 1999), efficiently addressing pathogen-rich wastes. Recognized as 'Class A' by the USEPA (Bruce R. Eastman, 2001), vermicomposting offers a controlled, rapid, and energy-efficient aerobic alternative to slow anaerobic composting (Fatin Amanina Azis, 2022). Managed by earthworms, it conservatively utilizes water, energy, and land, providing a sustainable, low-cost approach to organic waste treatment (Ecosan Services Foundation (ESF) and seecon gmbh, 2006). With its valuable properties and market appeal, Vermicompost improves soil health, promotes erosion control, and is a rich resource for organic amendments (Matthew Chekwube Enebe, 2023).

Figure 1. Mango Seed and Skins in the Dumping Ground

Considering these advantages, our research concludes that vermicomposting is the preferred technique for managing mango seed and skin waste in the Pran Natore factory. By leveraging the benefits of vermicomposting, the factory can effectively address its waste management challenges while contributing to environmental sustainability and agricultural productivity.

LITERATURE REVIEW

In reviewing the literature on waste management technologies, alternatives to vermicomposting include static pile composting, thermophilic composting, and pyrolysis (Matthew Chekwube Enebe, 2023). Static pile composting, involving aerobic decomposition in a stationary pile, is known for its simplicity and low operational costs. However, drawbacks such as longer processing times, potential odor issues, and uneven decomposition pose challenges (Zi Xiang Keng, 2023). Thermophilic composting, reliant on controlled microbial activity at elevated temperatures (Ilaria Finore, 2023), produces nutrient-rich compost but faces issues of slow biomass conversion, greenhouse gas emissions, and the need for sophisticated equipment. Pyrolysis, a technique converting biomass into biochar through heat in an oxygen-limited environment, offers benefits like carbon sequestration and enhanced soil health but encounters challenges like high energy requirements and greenhouse gas emissions (Manyà, 2012).

In contrast, vermicomposting emerges as a cost-effective and environmentally friendly waste management option. Its simplicity and independence from electricity and enzymes (Sakthivel, 2012) make it attractive, eliminating the need for complex machinery. Vermicomposting presents economic benefits by selling earthworms and features a self-regulated process with optimal conditions, leading to efficient waste decomposition and earthworm population expansion. Due to its practical advantages, vermicomposting is the preferred choice compared to other technologies.

METHODOLOGY

We utilized vermicomposting as the waste management technique, evaluating vital indicators like worm survival, biomass growth, and population expansion. Earthworm populations, subject to factors such as food, space, and environmental conditions, exhibit the potential to double every 60 to 90 days (Munroe, 2017), with mature breeders producing cocoons every 7 to 10 days (K. Samuel Sangtam, 2023). The decision to employ vermicomposting was based on its efficiency, cost-effectiveness, economic advantages through earthworm sales, and its environmentally friendly characteristics, aligning with the waste management objectives for the factory waste.

Experimental Setup

A small-scale compost plant was constructed adjacent to the mango pulping unit to minimize waste transportation costs. The plant featured 16 beds designed for processing approximately ten metric tons of mango seeds and skins. Each bed, measuring 5 feet in length, 2 feet in height, and 3 feet in width, had specific purposes, including composting, raw material storage, final output drying, and various other functions. The facility was enclosed by boundary walls to safeguard against birds, insects, and other predators. Recognizing the ideal temperature range for vermicomposting (15ºC to 25ºC) (Roohollah Rostami, 2009), the beds were strategically positioned 1.5 feet below the surface to leverage the cooler ground temperature. With Natore's historical weather data indicating an average temperature range of 25ºC-30ºC (Data and graphs for weather & climate in Natore, Bangladesh, 2024), additional measures such as a simple roofing system and cooling fans were implemented to maintain optimal conditions.

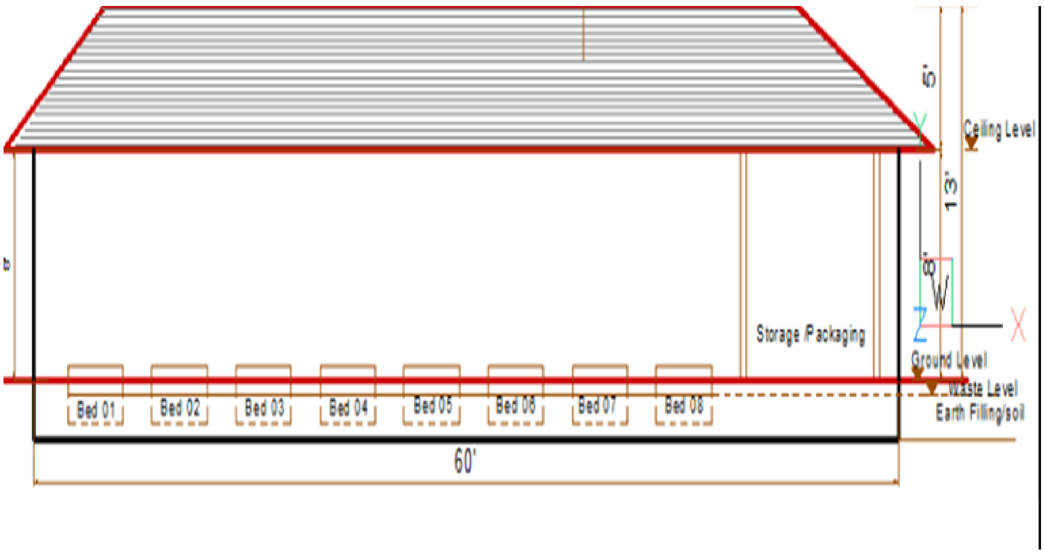

Figure 2. Elevation of the Compost Plant

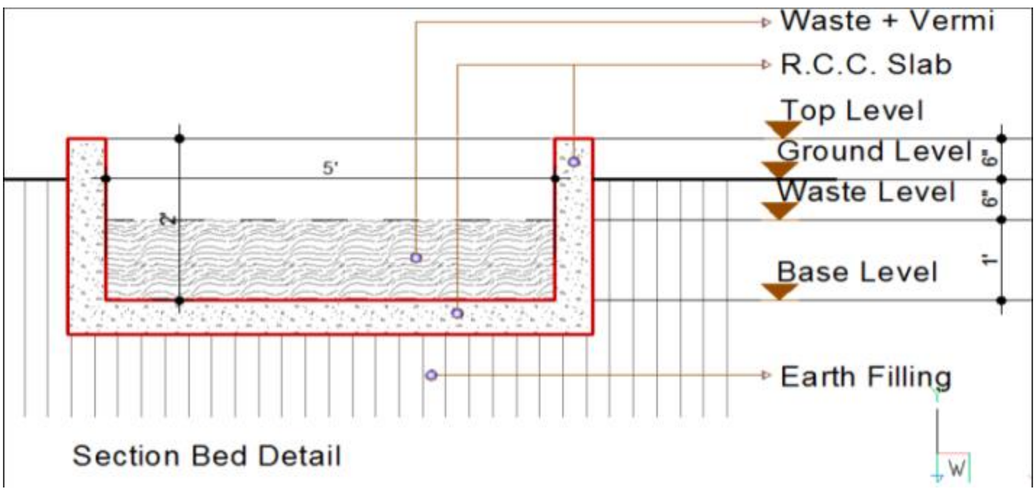

Figure 3. Cross-Sectional View of Worm Beds

Feed Processing

Mango seeds and skins were shredded using a machine, producing acidic waste with a pH range of 3.2-3.5. As worms thrive in a pH range of 6.5-7.5 (Why are My Composting Worms Trying to Escape?, 2023), adjustments were made using powdered limestone ($CaCO_3$) and crushed eggshells. After absorbing water, the limestone was mixed with the shredded waste to achieve a pH range of 7.0-8.0. Eggshells collected from the factory cafeteria were added to enhance worm digestion. Weekly turning of the beddings aided in controlling acidity and improving pH. The feeding layer was kept under 1 foot to prevent excessive heat generation.

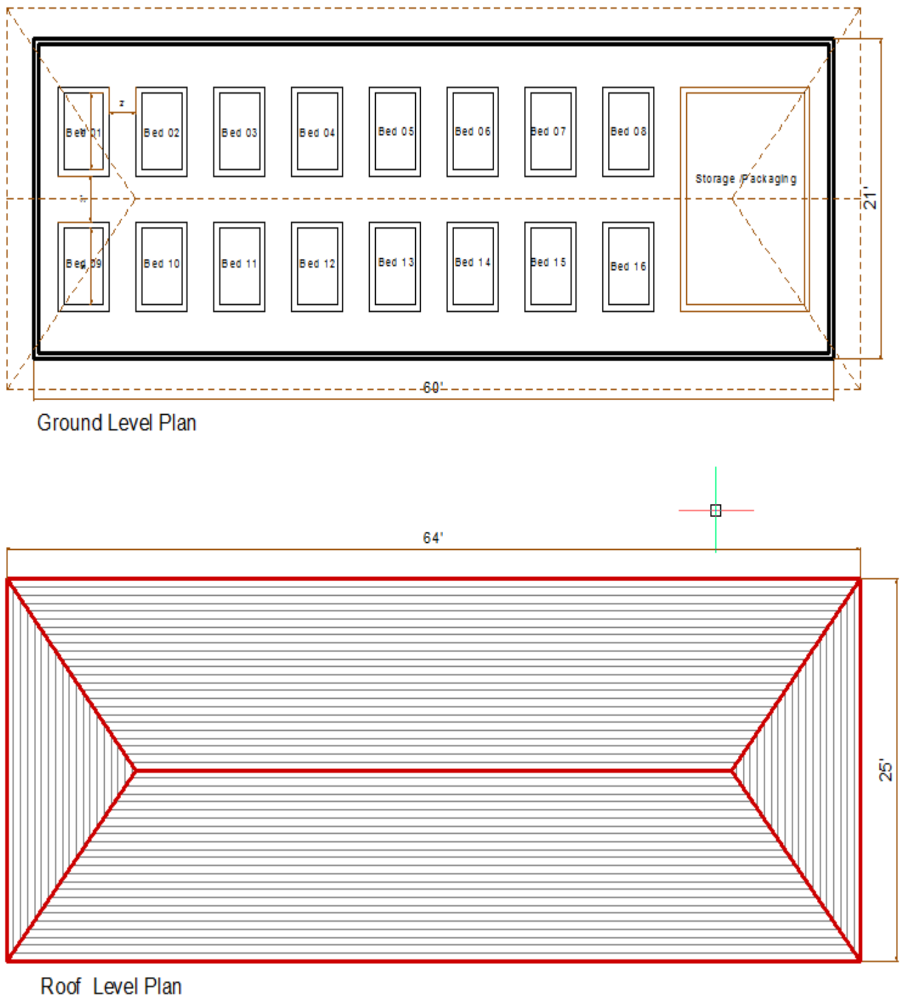

Figure 4. Plan of the Compost Plant

Figure 5. 3D View of the Vermicompost Plant

Stocking Earthworms

Eisenia foetida, commonly known as Red Wigglers, were chosen for their rapid growth and reproductive capabilities. With a breeding cycle of approximately 30 days from mating to egg-laying, the worm population can double every 60 days. These worms are robust, resilient, and adaptable to varying growing conditions. Red Wigglers exhibit remarkable tolerance to environmental fluctuations. Consuming organic materials equivalent to their body weight daily, they produce nitrogen, phosphorous, and potassium-rich castings amounting to 75% of their body weight (Red Wigglers (Eisenia Fetida), 2012). Sourced from a worm farm in Doulatpur, Kushtia, 0.5 million Red Wigglers were introduced to the Natore compost plant for waste processing and hatching.

Figure 6. Vermicompost Plant Under Construction

Bedding Conditions

Bedding, providing a stable habitat for worms, was carefully chosen to maintain an ideal moisture content of 45-60% (Rynk, 1992). Moisture levels were monitored using a moisture meter, and water was sprayed into the beds as needed. Vermiwash, a liquid bio-fertilizer collected during the passage of water through worms, served as a foliar spray, reducing plant diseases (Vasudeo Zambare, 2008). Adequate drainage facilities and collection points for vermiwash were implemented.

Process Monitoring

The process was monitored through olfactory cues, with a foul and wet smell indicating potential anaerobic conditions (pH of Your Soil and Worm Beds, 2024). Measures to address this included turning the bedding for improved aeration, incorporating dry paper waste and newspapers into the feed, and, if necessary, changing the feed and treating it with powdered limestone. Attention to these indicators ensured a healthy and efficient vermicomposting process.

Figure 7. Shredded Mango Seed and Skins

Figure 8. Monitoring Process and Outputs

RESEARCH RESULT AND DISCUSSION

In our 60-day vermicomposting experiment using mango processing waste, we produced an initial 20 kg fertilizer. Nets were employed to separate worms for continuous cycles, and a sample underwent nutrient testing at Mymensingh Agriculture University.

Table 1. Nutrient Composition of the Output Vermicompost Fertilizer

Element	Nutrient in output (%)
N (Nitrogen)	1.68
P (Phosphorous)	0.5081
K (Potassium)	1.487
S (Sulphur)	0.122
Na (Sodium)	3.3996
Zinc (Zn)	0.0155
Fe (Iron)	0.342
Mn (Manganese)	0.0096

B (Boron)	0.0081
Mg (magnesium)	0.48
Ca (Calcium)	5.34
Cu (Copper)	0.0031

The resulting fertilizer had a pH of 7.61, deviating from the recommended vermicompost pH (6.12±0.03) (Subler S, 1998). Nutrient composition was examined (Table 1) and compared with ideal values by Nagavallemma et al. (2004) for vermicompost and garden compost (Table 2).

Table 2. Ideal Nutrient Content in Vermicompost and Garden-compost Fertilizer (Nagavallemma, 2004)

Element	Nutrient in Vermicompost (%)	Nutrient in Garden compost (%)
N (Nitrogen)	0.51-1.61	0.8
P (Phosphorous)	0.19-1.02	0.35
K (Potassium)	0.15-0.73	0.48
Na (Sodium)	0.058-0.158	<0.01
Zn (Zinc)	0.0042-0.110	0.0012
Fe (Iron)	0.2050-1.3313	1.169
Mn (Manganese)	0.0105-0.2038	0.0414
Mg (Magnesium)	0.093-0.568	0.57
Ca (Calcium)	1.18-7.61	2.27
Cu (Copper)	0.0026-0.0048	0.0017

Key Findings

Nitrogen (N): Our vermicompost had 1.68% nitrogen, exceeding the ideal range (0.51-1.61%) and surpassing garden compost norms (0.28-0.61%).

Phosphorous (P): Phosphorous (0.5081%) aligned with vermicompost norms (0.19-1.02%) and garden compost recommendations (0.20-0.47%).

Potassium (K): Potassium (1.487%) exceeded the vermicompost range (0.15-0.73%) and surpassed garden compost norms (0.15-0.48%).

Sodium (Na): Sodium (3.3996%) surpassed the recommended vermicompost range (0.058-0.158%) and significantly exceeded garden compost levels (0.029-0.039%).

Other Elements: Zinc, Iron, Manganese, Magnesium, Calcium, and Copper either met or exceeded the suggested ideal ranges in both vermicompost and garden compost.

Overall Comparison: Our vermicompost successfully enriched nutrients, especially Nitrogen and Potassium. However, pH variations and elevated sodium levels suggest optimization areas. These findings provide insights into nutrient dynamics, emphasizing the need to refine the process for alignment with established benchmarks in both vermicompost and garden compost. Future research should identify factors influencing these deviations for sustainable organic fertilizer production.

Figure 9. Vermicompost Fertilizer from the Mango Seed and Skin in the PRAN Factory

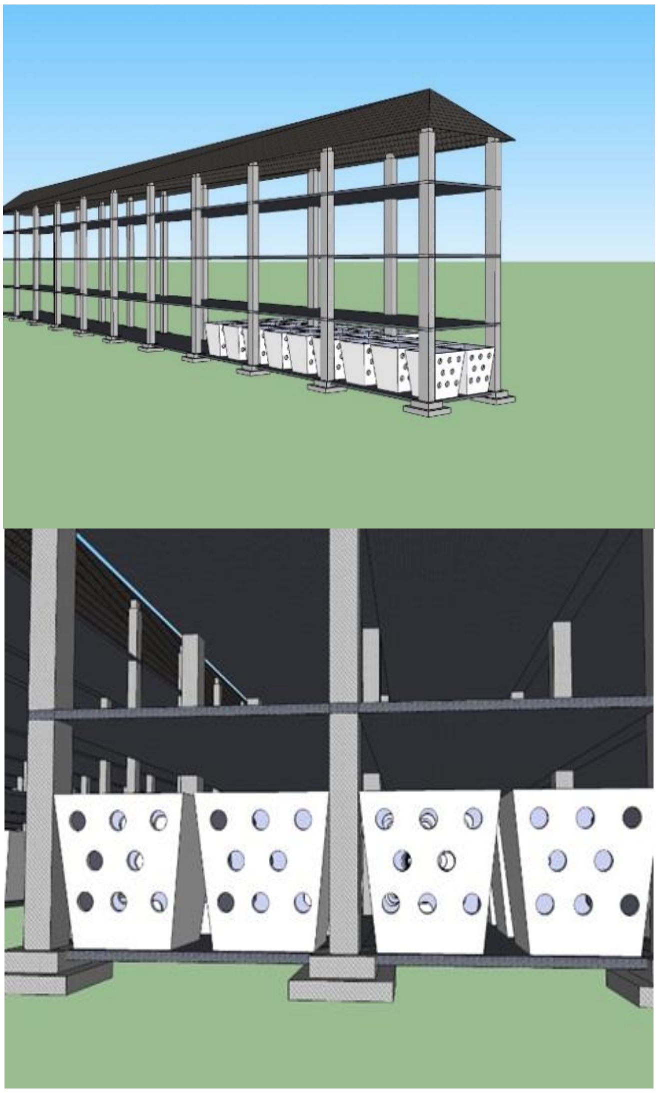

Figure 10. Stacking Plastic Waste Box in a Vertical Layer

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study demonstrate the significant potential for converting the substantial fruit waste generated by the Pran Natore factory into valuable vermicompost fertilizer. With an annual production of 15,000 MT of fruit waste, the proposed layout plan utilizing 1 acre of land could yield 5,000-6,000 MT of vermicompost fertilizer. The utilization of vertical stacking and perforated plastic boxes for waste collection and processing minimizes the required land area, offering an efficient and sustainable waste management solution. The suggested three-shade approach enhances the overall efficiency of the vermicomposting process. Moreover, the factory's connection with eighty thousand registered farmers presents a promising market for the organic vermicompost fertilizer: the farmers and the factory benefit by extending credit to farmers and adjusting prices during product buying seasons. Additionally, the potential to establish an organic food chain for the national and international markets adds further value.

Regarding business potential, the factory could produce 6,000 MT of output fertilizer, support 3,000-5,000 registered farmers, and generate a substantial business value of 1.2 million dollars (considering a fertilizer price of 200 USD/MT). These findings provide a viable waste management solution for Pran Natore and offer a scalable and replicable model for other food or fruit processing industries grappling with managing large quantities of organic waste. Implementation of this research has the potential to positively impact both environmental sustainability and economic viability for such sectors.

ADVANCED RESEARCH

Future research should focus on optimizing vermicompost production by refining layout plans and exploring innovative waste collection and processing techniques. Market expansion strategies are crucial for maximizing economic benefits by exploring domestic and international markets for organic vermicompost fertilizer. Comprehensive environmental impact assessments are necessary to evaluate sustainability and potential benefits in reducing greenhouse gas emissions and conserving natural resources. Additionally, conducting comparative studies with other waste management techniques and investigating scalability and replication to address organic waste management challenges on a broader scale are essential areas for further exploration.

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