



Research Paper

Production of Vermicompost from Pineapple Peel Waste: A Scientific Review and Application Potential in Circular Agriculture

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Abstract

This study examines the potential of transforming agricultural by-products into organic fertilizers, focusing on pineapple peel—a common yet underutilized agricultural waste. Often discarded improperly, contributing to environmental harm, pineapple peels are rich in organic matter, bromelain enzymes, and micronutrients, making them suitable for vermicomposting after necessary pre-treatment to counter their acidity and fermentation properties. A comparison with conventional substrates like cow manure and vegetable waste underscores the unique benefits and challenges of using pineapple peels. The study advocates a circular agriculture model leveraging vermicompost production from these peels, addressing waste management issues while promoting sustainable resource use and ecological preservation.

Keywords: *organic fertilizers, environmental management, pineapple peels, vermicompost.*

I. Introduction

Agricultural production and food processing have experienced notable growth over recent decades, particularly in developing countries. While this expansion has enhanced food security and economic prospects, it has also resulted in a significant increase in agricultural residues and organic waste, presenting considerable environmental challenges. Improper management of these materials can lead to soil degradation, water contamination, greenhouse gas emissions, and adverse health implications. Consequently, there is an urgent need to adopt sustainable waste management strategies that mitigate environmental harm while harnessing the value inherent in agricultural by-products. In response to these challenges, the concept of circular agriculture has gained traction as a transformative approach. This model emphasizes the reuse, recycling, and regeneration of biological resources within agricultural systems. By valorizing waste into useful products such as organic fertilizers, circular agriculture not only encourages ecological sustainability but also bolsters economic resilience. Among the range of technologies being explored, vermicomposting stands out as a promising method. It utilizes earthworms and microorganisms to convert organic waste into nutrient-rich compost, offering a practical and eco-friendly solution. Pineapple is one of the most widely cultivated tropical fruits, with key production centers in countries like Vietnam, Thailand, the Philippines, and Brazil. The industrial processing of pineapple generates substantial quantities of waste, predominantly from its peel and core. Remarkably, pineapple peel alone constitutes around 30–40% of the fruit's total mass, contributing significantly to organic waste output. Despite its richness in essential nutrients and enzymes, this by-product is often discarded without proper utilization, exacerbating environmental problems. The unique characteristics of pineapple peel—including its high moisture content, abundance of soluble sugars, and bromelain enzyme—make it inherently biodegradable. However, its acidic pH and tendency toward rapid fermentation pose challenges for direct application in biological treatments such as vermicomposting. Earthworms require stable conditions in terms of pH, temperature, and moisture for optimal activity. Addressing these constraints necessitates a well-planned approach to incorporating pineapple peel into vermicomposting processes. This research aims to provide a comprehensive analysis of the scientific foundations and practical considerations involved in utilizing pineapple peel for vermicompost production. By exploring its chemical composition, physical attributes, comparisons with conventional substrates, and potential integration into processing systems, the study seeks to contribute to advancing sustainable agricultural methods while enabling efficient waste management practices.

II. Contents

2.1. Global Perspective on Pineapple By-products and Waste Generation

The global production of pineapple has seen substantial growth thanks to rising demand for fresh fruit and processed goods like canned pineapple, juice, and dried fruit. This surge in production, however, has led to a significant increase in by-products, most notably pineapple peel. In many processing facilities, these residues are deemed waste and are typically discarded through landfilling or open dumping, leading to environmental challenges. Around the world, the management of pineapple waste remains inefficient, particularly in developing countries with limited waste treatment infrastructure. Nevertheless, recent studies have recognized the potential of pineapple by-products as resources for applications such as bioenergy generation, animal feed, composting, and various biotechnological processes. Notably, composting and vermicomposting stand out as sustainable and cost-effective solutions, especially for small- and medium-scale agricultural operations. The growing focus on sustainability and circular economy principles has spurred interest in innovative ways to repurpose pineapple waste. Converting pineapple peel into organic fertilizer not only mitigates environmental pollution but also boosts soil fertility and promotes sustainable agricultural practices.

2.2. Physicochemical and Biological Properties of Pineapple Peel

Pineapple peel is characterized by a complex chemical makeup, offering both advantages and challenges for biological processing. Rich in organic matter, it contains significant amounts of carbohydrates such as cellulose, hemicellulose, and simple sugars, which act as ideal substrates to support microbial activity and expedite decomposition. A noteworthy component of pineapple peel is bromelain, a proteolytic enzyme capable of breaking proteins down into amino acids. While this enzymatic activity enhances decomposition rates and accelerates organic transformation, excessive activity may disturb biological balance in certain systems—for instance, those heavily reliant on sensitive organisms like earthworms. Additionally, pineapple peel tends to have a low pH, typically spanning from 3.5 to 5.5. This acidity can suppress microbial diversity and pose risks to earthworm survival unless appropriately managed. The peel's high moisture content contributes further to rapid fermentation, often resulting in heat buildup and the release of volatile compounds during its breakdown. Overall, despite pineapple peel's nutrient-rich and highly biodegradable nature, its unprocessed inclusion in vermiculture systems is discouraged. To ensure compatibility with earthworm-based processes, pre-treatments such as pH adjustment, moisture reduction, and substrate stabilization are essential.

2.3. Comparison with Conventional Vermiculture Substrates

The selection of substrates in vermicomposting systems is pivotal for optimizing process efficiency and enhancing product quality. Conventional substrates like cow manure, straw, and vegetable waste are widely utilized owing to their favorable properties and widespread availability. Cow manure is often regarded as an ideal substrate due to its balanced nutrients, stable microbial populations, and nearly neutral pH levels, fostering optimal conditions for earthworm growth and reproduction. Straw is another common option; although its high lignin content slows decomposition, it improves aeration and ensures structural stability within the substrate. Meanwhile, vegetable waste decomposes quickly and provides essential nutrients, though improper handling may lead to odors and nutrient imbalances. In comparison to these materials, pineapple peel stands out for its rapid decomposition and elevated sugar content, which stimulate microbial activity. However, its inherent challenges—including high acidity and biological instability—make it less suitable for standalone use in vermiculture systems. Unlike cow manure, pineapple peel requires additional pre-treatment to enhance stability before use. An effective solution involves blending pineapple peel with traditional substrates to create a balanced mixture that supports earthworm health while maximizing nutrient recovery for agriculture.

2.4. Proposed Circular Model for Vermicompost Production Using Pineapple Peel

A circular agriculture-based model has been proposed to effectively repurpose pineapple peel as a substrate for vermicomposting. This approach focuses on optimizing resource efficiency, minimizing waste, and advancing sustainable agricultural practices. The process starts with collecting and preparing pineapple peel waste, where the material is cut into smaller pieces to increase its surface area and promote quicker decomposition. A pre-composting stage then follows to neutralize the material's acidity, stabilize microbial activity, and mitigate the presence of pathogens. During this phase, adding alkaline agents like lime or blending the peel with cow manure helps achieve a balanced pH. After pre-treatment, the conditioned material is combined with supplementary substrates to form an ideal feedstock for earthworms. This mixture is then placed in vermicomposting systems, where earthworms break down the organic matter, converting it into nutrient-rich vermicompost over several weeks. The harvested product serves as an organic fertilizer, promoting soil health and enhancing crop productivity. By adopting this closed-loop system, waste is minimized, and value is created, aligning with circular agriculture principles for a more sustainable production process.

2.5. Environmental and Economic Implications

Reusing pineapple peel in vermicomposting yields notable environmental advantages. It decreases organic waste sent to landfills, curtails greenhouse gas emissions, and limits the contamination of soil and water. Additionally, vermicompost enriches soil quality by improving its structure, boosting nutrient availability, and supporting sustainable farming techniques. Economically, turning waste into high-value fertilizers presents promising revenue opportunities for farmers and small-scale producers. Nevertheless, certain obstacles must be addressed for broader adoption, such as the seasonal availability of pineapple peels, the complexity of technical requirements, and the upfront costs of establishing vermiculture systems. The analysis underscores that while pineapple peel has tremendous potential as a resource in vermicomposting, it poses unique technical challenges. Its high content of easily degradable organic matter and bromelain enzymes accelerates decomposition compared to traditional substrates like straw. However, this rapid breakdown can lead to erratic temperature shifts and pH imbalances, making management a critical aspect of the process. One of the primary concerns is acidity. During its decomposition, pineapple peel significantly reduces substrate pH, creating an unfavorable environment for earthworms. To mitigate this challenge, pre-treatment is crucial in stabilizing the material before its introduction into vermiculture systems. In comparison to cow manure, which is already biologically stable, pineapple peel requires a more intricate processing regimen. Moreover, while the bromelain enzyme can facilitate faster decomposition at moderate levels, excessive concentrations may adversely affect earthworm health. This necessitates careful control of substrate composition and mixing strategies to optimize performance. A practical solution involves blending pineapple peel with other substrates such as cow manure or straw. This approach helps balance the carbon-to-nitrogen ratio while stabilizing the overall substrate. It also capitalizes on the distinct benefits of different materials to enhance the composting process. From an environmental viewpoint, leveraging pineapple peel reduces agricultural waste, mitigates pollution risks, and promotes circular economy practices where waste is recycled into valuable resources. On the economic front, vermicompost derived from pineapple peel holds substantial value within organic farming markets. However, ensuring a steady supply of raw materials and addressing technical requirements for scalability remain key factors to overcome.

III. Conclusion

Pineapple peel emerges as a highly promising yet underutilized resource for sustainable agriculture and waste management. Its high organic content and rapid biodegradability make it an ideal candidate for vermicomposting; however, its pronounced acidity and accelerated fermentation rate necessitate adequate pre-treatment and continuous substrate optimization. Integrating pineapple peel into vermiculture systems via a circular agriculture framework offers ecological benefits and economic prospects alike. Moving forward, research efforts should prioritize refining processing techniques, exploring feasibility at larger scales, and developing standardized protocols for practical implementation.

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