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# Production of Biofertilizer from Fruit and Garden Waste

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## ABSTRACT

*The project focused on the production of bio-fertilizer from fruit and garden waste, with a specific emphasis on utilizing pineapple tops in the composting process. The objective was to produce and assess the properties of the bio fertilizer obtained from this process and evaluate its potential application in agriculture. In this study, the composting process was done in a 0.7 m long, 0.85 wide and 1.1 m high vessel, and 0.238 $m^3$ pineapple top wastes, resulting in 0.35 $m^3$ of biofertilizer. The bio fertilizer produced exhibited favorable characteristics, including a moisture content of 36%, pH of 7.1, and a total organic matter content of 40.4%. Analysis revealed that the bio fertilizer contained levels of potassium 5770 ppm, lead 60 ppm, and cadmium 2 ppm. These properties indicate that the bio fertilizer has favorable moisture content, neutral pH, and significant organic matter. Additionally, it contains potassium in significant quantities while having low levels of lead and cadmium, ensuring its safety for agricultural use.*

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## INTRODUCTION

The world's population is expected to increase to 9 billion by 2050, resulting in 70-100% need for more food (Hemathilake & Gunathilake, 2022). Therefore, demands placed upon agriculture to supply future food will be one of the greatest challenges facing the agrarian communities. In order to meet this challenge, focusing on the soil biological system and understanding its complex processes and interactions governing the stability of crop production and soil health is of great importance (Bahadur *et al.*, 2014). Generally, in conventional agriculture there are two two major inputs are necessary for crop production: fertilizer and pesticide. In other words, it can be said that fertilizer is food and pesticide is medicine for plants. Plants require certain mineral nutrients for their growth; however, there has been a continuous loss of these nutrients in the soil as a result of the imbalanced use of chemical fertilizers, leading to severe fertility loss (Chaudhari *et al.*, 2022).

The high utilization of chemical fertilizers causes poor soil health due to lack of organic matter together with loss of inherent fertility by affecting soil micro flora and fauna. It also has negative impacts to the health of human beings and animals consuming crops and plants which have been subjected to intensive fertilizer (Hossain *et al.*, 2022). Moreover, plants cannot uptake all the nutrients applied through chemical fertilizers so, some amount of nutrients are either fixed in the soil or leached out and ultimately mixed with water bodies, leading to eutrophication and water pollution (Rashmi *et al.,* 2020). In order to make agriculture sustainable, it is necessary to implement a balanced and reasonable use of nutrients which are cost cost-effective and eco-friendly in that case, bio fertilizer could be a suitable option (Mahanty *et al.*, 2017; Verma *et al.*, 2020).

On the other hand, the disposal of solid wastes is a stinging and widespread problem both in rural and urban areas in many developed and developing countries. It is estimated that in Tanzania, organic solid wastes are the most generated solid wastes, with the rate of >2 tons/ day equivalent to 72% of the overall solid waste generation (Nyampundu *et al.,* 2020). The production of organic wastes, fruits and garden wastes included; is at a very high rate, which must be properly managed in order to protect human health and the environment as well as preserve the natural resources. When organic wastes decompose on in uncontrolled landfills, they produce methane gas, which is one of the major greenhouse gases contributing to a drastic change in the surrounding climate and environment (Aziz *et al.,* 2020). Improper disposal of the organic wastes also lead to the spread of infectious diseases, land and water pollution alongside the obstruction of drains (Isaiah & Blessing, 2020).

Therefore, instead of disposing of fruits and garden wastes which contain important plant nutrients, the wastes can be microbial decomposed through composting to produce biofertilizer (Ayilara *et al.,* 2020; Indumathi, 2017). Biofertilizers are substances that contain microorganisms that when added to the soil, they restore its fertility and help to uptake both macro and micro nutrients for plant growth (Asoegwu *et al.,* 2020; Daniel *et al.,* 2022). This is through nitrogen fixation, phosphate and potassium mineralization and biodegradation of organic matter (Chakraborty & Akhtar, 2021, Devi & Sumathy, 2017). Research has been done on the use of vegetable waste (Indumathi; 2017), food waste (Jamaludin *et al.,* 2017) and agro waste (Lim & Matu, 2015) to produce biofertilizer but few has been done on garden and fruit wastes (Jadhav *et al.,* 2022).

Tanzania is one of the leading countries in East Africa in pineapple production, accounting for 19% of total production and ranking 18th among the top 20 pineapple-producing countries in the world (Haji & Babune, 2023). The total area cultivated with pineapple in Tanzania is 17,360 ha (Firatoiu *et al.,* 2021); with a yearly consumption of 366,277 metric tonnes. The crop is mainly grown in Bagamoyo, Kibaha, Geita, Mwanza, Tanga, Mtwara, Lindi, and Zanzibar. It is anticipated that pineapple consumption in Tanzania would be around 370,000 metric tons, with production of 549,000 metric tons by 2026 (Haji & Babune, 2023). Studies have been done on the use of pineapple waste especially peels (Alasa *et al.,* 2021; Muhammad *et al.,* 2023) but the focus of this study was to produce and assess the properties of the biofertilizer obtained from pineapple tops and evaluate its potential application in agriculture.

## METHODS AND MATERIALS

### Raw materials collection and preparation

The raw materials for the biofertilizer production were fruits (pineapple tops) and garden wastes. The fruit wastes were collected from the Msewe and Mabibo fruits market. To have clear information on the availability of raw materials, i.e., pineapple tops, samples of pineapple fruits were used to measure their weight and the weight of removed tops to see the composition of the pineapple tops in the whole fruit. The garden waste used during the composting process was dry leaves, and fresh grass clippings. Dry leaves were used as a moisture aid to promote aeration, prevent excessive compaction, and provide carbon for compost. Fresh grass clippings were added to supply nitrogen and balance the compost pile's carbon-to-nitrogen ratio. The grass clippings and dry leaves were collected from the University of Dar es Salaam garden. For this study a total of 10 kg of the waste was used, consisting of 7.5 kg (75%) of pineapple tops and 2.5 kg of other waste. The wastes were transported to the microbiology lab for further processing. The samples were sorted to remove any contaminants, such as plastics or metals, and were chopped into small, uniform pieces using a garden shredder. The prepared samples were then thoroughly mixed to ensure a homogeneous sample for analysis.

### Physical-chemical characterization of the waste sample

The waste samples were subjected to various physical and chemical tests to determine their suitability for composting to produce the bio fertilizer.

***Moisture content:*** The percentage of moisture content of the waste samples was determined using the gravimetric method for moisture determination as described by Zambrano *et al.,* (2019) using an oven, desiccator, weighing dish, and analytical balance. The weighing dish was placed on an analytical balance, and the balance was zeroed. A ground quantity of the sample was placed into the weighing dish to determine the weight of the sample, W1. The weighed sample was then transferred to a drying pan and spread out in a thin layer. The drying pan was placed in an oven preheated to 105°C, and the sample was dried until it reached a constant weight. The drying pan was removed from the oven and placed in a desiccator to cool. Once the sample had cooled to room temperature, the weight of the dry sample was measured and recorded as W2. The moisture content was calculated using Equation 1.

$$\%MC = ((W1 - W2))/W1 \ \times 100 \qquad (1)$$

where MC is the moisture content; W1 is the weight of the wet sample and W2 is the weight of the dry sample.

***Total organic matter:*** The crucible and its cover were weighed as W1, and the crucible with the dried sample before incineration was weighed as W2. The crucible with the dried sample was placed in a muffle furnace preheated to 550-600°C. The sample was combusted at high temperature, burning away all organic matter and leaving only the inorganic residue. After incinerating the sample for two hours, the crucible was removed from the furnace using tongs and placed in a desiccator to cool. Once the sample had cooled to room temperature, the crucible and its residue were weighed, and the weight was recorded as W3. The total organic matter content of the sample was calculated using Equation 2.

$$\text{Total organic matter} = \frac{(W2 - W3)\times 100\%}{(W2 - W1)} \qquad (2)$$

where W1 is the weight of the crucible and cover, W2 is the weight of the crucible and sample before incineration, and W3 is the weight of the crucible and residue after incineration.

***Carbon Nitrogen ratio:*** The carbon to nitrogen (C:N) ratio was determined using Equation 3.

$$\text{C: N ratio} = \frac{(\%TOM \times 12)}{14} \qquad (3)$$

where % TOM is the percentage of organic matter, 12 and 14 is the atomic weight of carbon and nitrogen respectively.

***pH:*** The pH for the compost was expected to be around 6-8 for the proper growth of microorganisms. The reagents used included distilled water, buffer solutions of known pH, a pH meter, stirring rod, and a container. A representative sample of the fruit and garden waste was taken. The pH meter was calibrated using buffer solutions of pH 7.00. The sample was placed in a container, and distilled water was added in a 1:5 ratio (1-part sample to 5 parts water). The mixture was thoroughly stirred with a stirring rod to ensure a uniform sample. The pH electrode was fully immersed in the sample, and the pH reading was allowed to stabilize on the pH meter display. The pH reading was recorded. The density was measured by taking a sample of the biofertilizer, measuring its mass then using water displacement method to measure the volume.

**Production of biofertilizer**

The composting process was done in a 0.7 m long, 0.85 wide and 1.1 m long vessel. The height to which the pineapple wastes were arranged was 40 cm, resulting to a volume of 0.238 cubic meters (0.4*0.7*0.85). The compost was arranged in layers. A layer of dry leaves was placed at the bottom of the compost pile to aid in moisture absorption, to promote aeration and prevent excessive compaction and provide carbon for the compost. Subsequently, a layer of pineapple tops was added to provide potassium for the compost. On top of the pineapple tops, a layer of fresh grass clippings was added, supplying nitrogen and balancing the carbon-to-nitrogen ratio in the compost pile. Then a layer of garden soil was placed at the bottom of the compost pile to provide a base layer of microorganisms that would help break down the organic material.

The layers were added in a manner of alternating green (nitrogen-rich) and brown (carbon-rich) materials until the compost pile reached a height of approximately 1 meter. After adding each layer, the compost was watered to maintain dampness without becoming overly saturated. For the first two weeks the compost was turned after 3 days, and then afterwards, it was turned once a week. The compost pile was turned once a week to mix the materials and provide oxygen to the microorganisms responsible for breaking down the organic matter. Figure 1 shows the vessel used for composting.


**Figure 1: The vessel used for composting.**

**Testing the quality of the biofertilizer produced**

The quality of the produced fertilizer was tested by analyzing its moisture content, pH, Temperature, concentration of potassium and heavy metals. Procedures for pH testing are the same as mentioned earlier in the text. The method by Yue *et al.*, (2022) was adopted in the determination of potassium (K) using Microwave Plasma -Atomic Emission Spectroscopy (MP-AES). A representative sample of the bio fertilizer was taken, weighing 0.5 grams. The sample was transferred to a conical flask, and 10 mL of concentrated nitric acid was added to dissolve the organic material with deionized water to a total of 50 mL. A series of calibration standards were prepared with known concentrations of potassium, ranging from 5 to 50 mg/L, using appropriate volumes of potassium stock solutions and dilutions with acid. The instrument was set up with specific parameters, including the wavelength of the potassium emission line and an integration time of 10 seconds. Subsequently, the digested sample was analyzed, and the emission intensity of the potassium line was measured.

**Quality Assurance (QA) and Quality Control (QC)**

***Process Monitoring:*** The key parameters such as temperature, pH, and moisture content were regularly monitored throughout the composting process.

***Turning Frequency:*** The compost pile was turned once every three days for the first two weeks. It was subsequently turned every seven days for the next five weeks to improve aeration and microbial activity.

***Quality Control* (QC) (*Compost Sampling):*** Samples were collected at various stages of the composting process to assess the physical and chemical characteristics using laboratory tests to measure parameters such as moisture content and pH to ensure the compost meets desired specifications.

***Maturity Assessment:*** Maturity of the compost was evaluated to ensure that it is stabilized and ready for use. The color of the matured biofertilizer was dark brown, which indicates the breakdown of organic materials into humic substances, resulting in a rich, soil-like appearance and crumbly texture containing no recognizable pieces of organic materials.

## RESULTS AND DISCUSSION

### Physical-chemical characterization of pineapple waste

It was found that in an average one kilogram of pineapple produces at least three grams of pineapple tops. Considering the yearly consumption of pineapples in Tanzania, which amounts to 366,277 metric tonnes, it is possible to produce a significant amount of bio fertilizer through composting using pineapple tops. Of which, for a consumption of 366,277 metric tonnes of pineapples, 109,883 metric tonnes of pineapple tops waste will be generated which can be used to produce the bio fertilizer. The pineapple waste characterization results show that it contains 58% moisture, 84.8% organic matter, and a C: N ratio of 72.6.

### Production of Bio-fertilizer

In this study, 0.238 $m^3$ of pineapple top waste were employed, resulting in 0.59 m height and 0.35 $m^3$ final volume of bio fertilizer production. Thus, for every 109,883 metric tonnes of pineapple top waste, roughly 96,897 metric tonnes of bio fertilizer will be produced. For an average application of 302,450 tonnes of chemical fertilizer per season in Tanzania, of which approximately 75% is imported (Benson *et al.*, 2012, Lema *et al.*, 2014), the 96,897 metric tonnes of bio fertilizer will contribute to reduce chemical fertilizer imports (Ornella & Fan, 2024). With a predicted pineapple production of 549,000 metric tonnes by 2026, the contribution will be considerably greater. Figure 2 shows the bio fertilizer produced.

**Figure 2: The matured bio fertilizer.**

The variation of temperature, moisture content, pH and total organic matter during composting is shown in Figure 3 to Figure 6.

### Temperature

The temperature variation is presented in Figure 3. The temperature sharply rose from an ambient temperature to 53°C after 3 days.

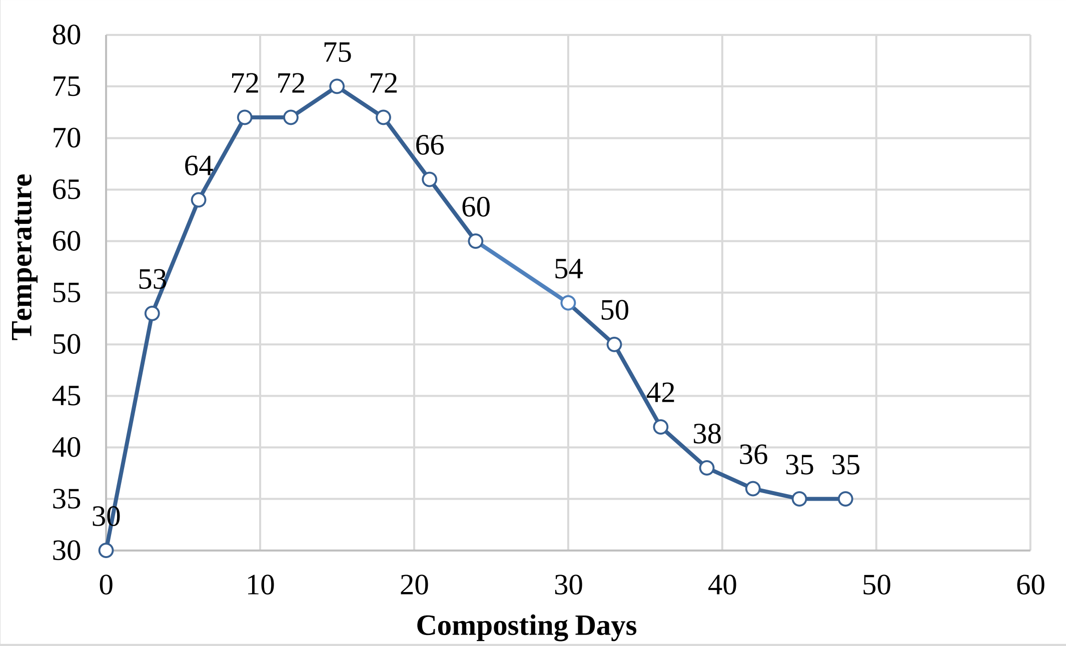


**Figure 3: Temperature variation during the composting period.**

This abrupt temperature increase in temperature is an indication of the increasing microbial activity when utilizing the compost material. This phase is usually characterized by an abundance of mesophilic microorganisms. However, as the temperature rose to 68°C, the mesophiles conditions became unfavorable, while the microbial community's thermophiles started to thrive. This group of microbes would first need to acclimatize before growing. This was probably the reason for the observed plateauing in the temperature. Thereafter, the temperature steadily rose to 72°C, at day 9 and stayed relatively constant at 72–75°C until day 18. During this thermophilic phase, the microbial activity is at its highest. However, as the nutrients diminish, the microbial activity decrease, leading to the cooling phase, where temperatures fall (days 21–33) where mesophiles also finish breaking down the compost. This tendency was also observed by Zakarya *et al.,* (2018) when composted rice straw. The temperature tends to approach the ambient temperature from day 42, which is said to mature when the temperature of the pile corresponds with the surrounding temperature.

## Moisture Content

As shown in Figure 4, at the beginning of the composting period the moisture content was recorded to be 58%. However, it began to fall as noted at day 7 with 55% moisture content. This was a result of the mesophilic microbes breaking down the organic matter leading to the rise in temperature and use of moisture. There was a sharp decrease in moisture content with 43% at day 15 being the lowest percentage. This is due to the existence of the thermophilic phase leading to the increase in temperature to 75°C where microbial activity is at its highest. On day 16, water was added to the pile to prevent the moisture percentage from falling below 40, which is the minimum allowed percentage for effective composting, hence the increase to 49% even when the temperature was rising. The moisture then continued to fall steadily as microbial activity continued taking place to a final 36% at day 49 where the compost had matured.

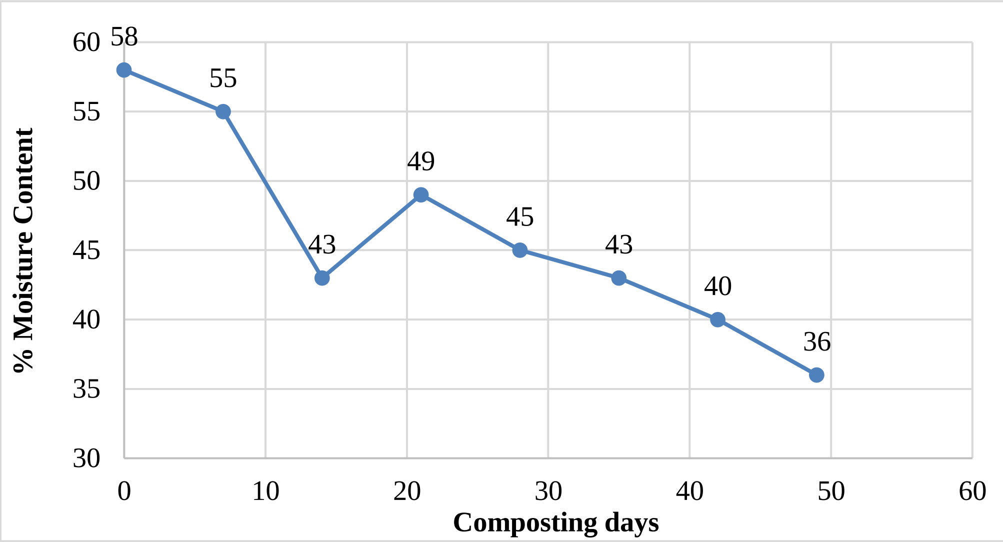


**Figure 4: Moisture content variation during the composting period.**

### *pH*

The initial composting mixture was acidic at a pH of 5 and the acidity further increased to 4.4 after day 2 as shown in Figure 5. The acidity is due to the organic acids, such as acetic acid, that are naturally produced during the fermentation of the food waste.

A part of the organic acids will be neutralized by the alkaline gas. However, when the pH rises above 6.5, the buffering capacity of the organic acids decreases and leads to the release of $NH_3$. This was probably the reason for the observed steady increase in the pile's pH. After the depletion of the nitrogen sources, the production of $NH_3$ will cease and the pH will approach neutral. After day 20, the pH of the pile fluctuated within 6.5~7.1, suggesting that the nitrogen source was depleting, which slowed down the microbial activities.

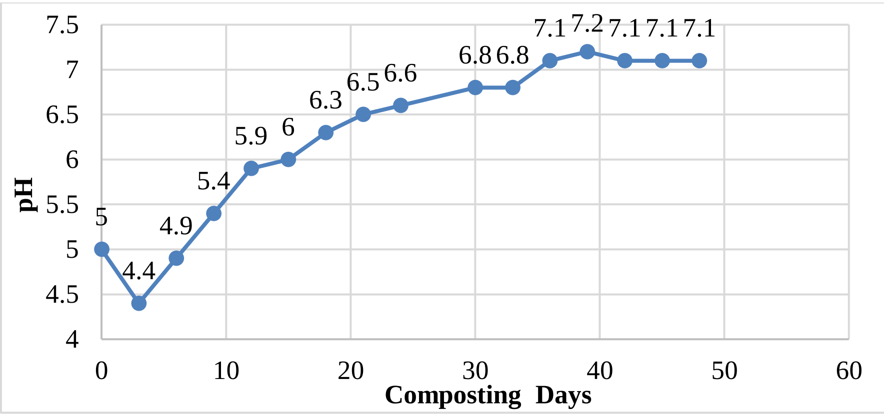


**Figure 5: pH variation during the composting period**

### *Total organic Matter*

Figure 6 shows that at day 0 (Start); the initial total organic matter content was 84.8%. This indicates the beginning of the composting process, with all organic components present. After one week of composting, the total organic matter level dropped to 76%. This reduction is the result of microbial decomposition and the breakdown of organic materials into simpler forms. By the end of the second week (day 14), the total organic matter content had dropped to 55.6% as microbial activity continued to degrade the organic components, resulting in an additional decrease. The overall organic matter content reached 50.3% by the end of the third week, as organic matter continued to decompose and change into microbial biomass, carbon dioxide, and other forms. The total organic matter content kept decreasing up to 40.4% at the end of week 7. The compost had undergone extensive decomposition, transformation, and maturation, decreasing the organic matter content.

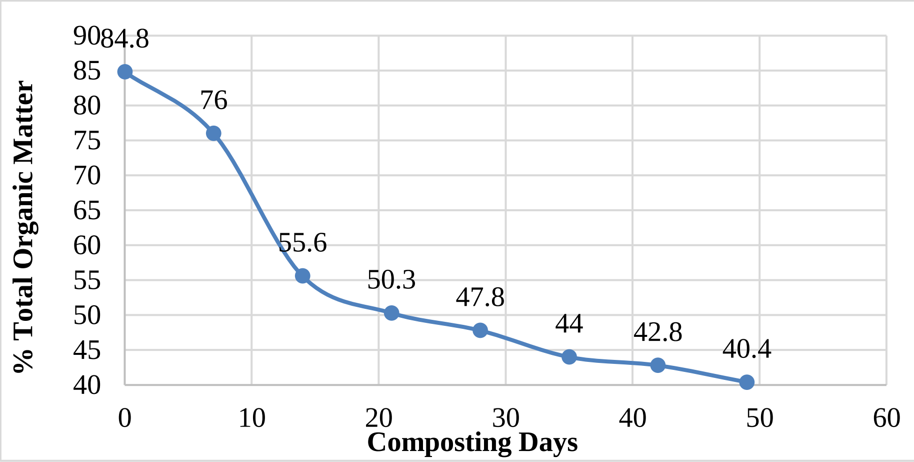


**Figure 6: Total Organic Matter variation during the composting period.**

## Physical-chemical characterization of the produced bio-fertilizer

The quality of the bio fertilizer was determined by measuring the moisture content, pH, Temperature, concentration of potassium and heavy metals if present. The produced biofertilizer contain potassium in significant quantities. The bio fertilizer should have about 0.5% w/w Potassium and maximum pH of 6.5-7.5 (Ozores-Hampton, 2017). Other parameters are a shown in Table 1. The bio fertilizer produced was within the standard ranges of the physical and chemical properties required in a good quality bio fertilizer.

**Table 1: Physical-chemical characteristics of the produced bio fertilizer**

| Property | Property value | Required range (Ozores-Hampton, 2017) |
|---|---|---|
| **Moisture content (%)** | 36 | 30 to 60 |
| **pH** | 7.1 | 5.0-8.0 |
| **Temperature(°C)** | 35 | 30-40 |
| **Potassium (ppm)** | 5770 | 1000-35000 |
| **Lead (ppm)** | 60 | <300 |
| **Cadmium (ppm)** | 2 | <15 |

## CONCLUSION AND RECOMMENDATIONS

The bio fertilizer was produced specifically using pineapple tops in the composting process, with the following properties: Moisture content 36%, pH 7.1, Total Organic Matter 40.4%, and temperature of 35°C. The produced biofertilizer quality showed that it contains: potassium 5770 ppm, lead 60 ppm, and cadmium 2 ppm. These properties indicate that the bio fertilizer has favorable moisture content, neutral pH, and a significant amount of organic matter. Additionally, it contains potassium in significant quantities while having low levels of lead and cadmium, which ensures its safety for agricultural use.

In this study, 0.238 $m^3$ of pineapple top waste were employed, resulting in 0.35 $m^3$ of bio fertilizer production. Thus, for every 109,883 metric tonnes of pineapple top waste, roughly 96,897 metric tonnes of bio fertilizer will be produced. For an average application of 302,450 tonnes of chemical fertilizer per season in Tanzania, of which approximately 75% is imported the produced bio fertilizer will contribute to reduce chemical fertilizer imports. With a predicted pineapple production of 549,000 metric tonnes by 2026, the contribution will be considerably greater. Thus, this study suggests that bio fertilizer can benefit the agriculture industry by enhancing soil health and perhaps lowering reliance on synthetic fertilizers.

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