Macro-Nutrient Composition and Feasibility of Fruit Wastes as Agricultural Amendments

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Abstract

Fruit waste is an extensive problem, especially in areas where perishable fruits possess a short shelf life, resulting in considerable waste. A method of recycling fruit waste involves using it as a soil amendment, which can reduce the environmental harm caused by artificial fertilisers while supplying essential nutrients to plants from the soil. This study seeks to evaluate the feasibility of particular tropical fruit byproducts as soil amendments. Four diverse fruit varieties were analysed for their nutritional value: pineapple, coconut, watermelon and orange peels. Analysis of nutrient content using ICP-OES revealed that pineapple waste included the highest Magnesium (Mg) concentration at 2420.67 mg/kg, but watermelon rinds displayed the highest Potassium (K) levels at 37426.67 mg/kg and Phosphorus (P) at 2675.33 mg/kg. Concurrently, orange peels had the highest calcium (Ca) concentration at 7756.00 mg/kg among the assessed samples. Nutrient analysis using ICP-OES concluded that pineapple waste contained the highest Magnesium (Mg) concentration, while watermelon rinds exhibited the highest levels of Potassium (K) and Phosphorus (P) in a notable trend. A one-way ANOVA reveals that watermelon rinds have the highest nutritional value and considerable potential as soil amendments, with a p-value<0.05 indicating statistical significance. This indicates the possibility of employing fruit waste as an alternative nitrogen source for soils, thereby alleviating the surplus waste in the market by repurposing it for soil fertilisation.

Keywords: *Fruit Waste Recycling, Soil Amendments, Nutrient Analysis, Organic Fertilizer, Waste Valorization*

1. Introduction

The extensive use of chemical fertilisers and pesticides in agriculture results in soil and groundwater contamination. The primary classifications of fertilisers are inorganic and organic fertilisers. The overuse of inorganic fertilisers diminishes soil quality and fertility. Organic fertiliser outperforms inorganic fertiliser by increasing soil carbon levels and reducing nitrogen runoff [1]. The worldwide accumulation of fruit waste poses significant environmental and economic challenges, intensifying landfill overuse and greenhouse gas emissions. In Malaysia, where tropical fruit production is essential to agriculture, the potential to transform fruit waste into organic fertiliser aligns with governmental goals for sustainable development and waste reduction. This approach converts fruit waste

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into valuable soil nutrients, tackling waste disposal issues while fostering sustainable agriculture practices, reducing reliance on chemical fertilisers and improving long-term soil health.

Pineapple waste, primarily consisting of peels, crowns and residual pulp, is generated in significant quantities in Malaysia due to the nation's robust pineapple industry, catering to both domestic consumption and export markets. These wastes are often discarded or poorly used, despite their rich nutritional content. Pineapple waste consists of substantial organic matter that might enhance soil structure. In Malaysia, pineapple waste is sometimes employed as animal feed or composted for small-scale agriculture. Nevertheless, its potential as a soil supplement has not been thoroughly explored. The incorporation of pineapple waste into soil improves nutrient availability and stimulates crop growth, establishing it as a feasible organic fertiliser alternative [2].

The substantial processing of oil, milk and other products generates considerable coconut flesh waste from Malaysia's thriving coconut industry. This waste, comprising husk and residual pulp, is typically utilised little in composting. Coconut meat waste, abundant in organic carbon, contains moderate amounts of essential elements such as phosphorus (P) and potassium (K), enhancing soil fertility. In coastal regions, conventional Malaysian agriculture intermittently uses coconut trash to enhance soil moisture retention and structure. Providing an affordable alternative to synthetic fertilisers, its nutritional makeup facilitates its application as a sustainable soil amendment [3].

Malaysia produces substantial quantities of watermelon rinds, primarily from fresh-cut fruit markets, juice production and household consumption. In Malaysia, watermelon rinds are hardly utilised for biogas production or composting. Their nutrient richness renders them ideal for soil enhancement, thereby augmenting fertility and fostering robust plant growth. Utilising watermelon rinds as organic fertiliser could sustainably benefit Malaysia's tropical ecosystem by reducing waste [4].

Due to the extensive utilisation of citrus fruits in both fresh and processed formats, including beverages and snacks, substantial quantities of orange peel waste are produced in Malaysia. Frequently discarded in landfills, these peels exacerbate waste management challenges. While orange peels are occasionally utilised in home gardening or small-scale composting in Malaysia, they have not been widely adopted in commercial agriculture. Their high availability and nutritional composition render them an effective soil supplement for enhancing agricultural productivity and soil quality [5].

The utilisation of fruit waste to enhance agricultural productivity is not a novel concept. The likelihood of these pollutants affecting crops diminishes as waste management systems improve. Previous studies examined the differential responses of agricultural and horticultural crops to compost versus raw plant waste. Chiew et al. [6] assert that the effective management and utilisation of constrained land for food production rely on sustainable agricultural practices and the repurposing of agricultural waste and byproducts. Utilising food waste on agricultural land sustains soil fertility. This study analysed several fruit wastes prevalent in Malaysia, based on their nutritional makeup, to determine the most suitable option for soil amendments.

2. Methodology

2.1. Sample collection

The fruit-derived materials, comprising pineapple peels, coconut meat waste, watermelon rinds and orange peels, were collected from various shops and restaurants that discard such fruit waste. These establishments offer pineapple peels, coconut flesh remnants, watermelon rinds and orange peels. Pineapple peels, watermelon rinds and orange peels were gathered from the establishment in Ayer Keroh, referred to locally as D'Puteh Restaurant. Coconut meat waste was gathered from Santan Segar Sri Duyong.

2.2. Sample preparation

Each fruit sample was separated and diced into smaller portions using a knife. The samples were placed in an oven at a temperature of 80 ºC until a constant weight was attained [7]. The desiccated samples were pulverised to yield a powdered form of the material. The specimen was prepared in the Soil Science Laboratory at the Jasin Campus of Universiti Teknologi MARA.

Figure 1 Figure description (a) Dried coconut flesh waste; (b) Dried pineapple waste; (c) Dried orange peels; (d) Dried watermelon rinds

2.3. Mineral composition

The minerals analyzed in this study included Phosphorus (P), Potassium (K), Magnesium (Mg), and Calcium (Ca). A 0.5 g sample of the ground material was measured and documented utilising the calibrated crucible. The crucible was subsequently placed inside a soundproof furnace. The temperature was initially set at 300 °C for one hour, then gradually raised to 550 °C over a duration of 7 hours. Upon extinguishing the furnace, the crucible was positioned in a desiccator for gradual cooling. Following the addition of 2 cc of strong HCl to hydrate the ash, the samples were positioned on a heated plate until all moisture was eliminated. 10 ml of a 20% HNO3 solution was introduced into each crucible. The crucible was positioned in a water bath at 100 °C. The mixture was diluted to a final volume of 100 ml with distilled water using a volumetric flask. The substance was placed in a 100 ml vial after filtration. An inductively coupled plasma optical emission spectrometer was utilised.

2.4. pH determination

The pH levels of the fruit waste samples were assessed to evaluate their acidity or alkalinity using a calibrated glass electrode pH meter, in accordance with the standardised procedure established by [8]. This approach required meticulous sample preparation to guarantee precise measurements, employing a pH meter to evaluate the hydrogen ion concentration in the fruit waste extracts, thereby offering a dependable assessment of their acidic or alkaline characteristics.

2.5. Statistical analysis

The macro-nutrient composition data obtained were statistically analysed by one-way ANOVA using Statistical Package for the Social Sciences (SPSS) version 21.0. The significant differences among treatments were tested using Tukey post hoc.

3. Results and discussion

3.1 Mineral content in fruit wastes

This study offers a thorough investigation of the nutrient profiles of several fruit wastes, including pineapple, coconut flesh, watermelon rinds and orange peels, as detailed in Table 1, which outlines their chemical composition. The table indicates that watermelon rinds contain significantly elevated quantities of Potassium (K) and Phosphorus (P), measuring 37,426 mg/kg and 2,675.33 mg/kg, respectively. Pineapple waste exhibits the greatest Magnesium (Mg) concentration among the analysed samples, measuring 2,420.67 mg/kg. Likewise, orange peels are distinguished by their high Calcium (Ca) content, recorded at 7,756.33 mg/kg, the most among the assessed fruit wastes. The statistical analysis in the study indicates considerable differences in nutrient content among different fruit wastes, highlighting the variety in their chemical compositions.

The study by [9] ascribes the observed variations in mineral and trace element levels to several factors, including fruit variety, ripeness stage, soil type, soil conditions and irrigation practices. These factors contribute to disparities across various fruit varieties as well as to variances within different sections of the same fruit, affecting their total mineral compositions.

Minerals are essential for various physiological processes in the human body, especially in structural development and regulatory activities. Fruits and their by-products, including peels and rinds, are acknowledged as significant sources of dietary minerals, as indicated by [10]. This viewpoint corresponds with the research of [11], which indicated that orange peels possess the greatest calcium concentration among various fruit wastes, hence underscoring their potential as a significant mineral source. These observations underscore the nutritional importance of fruit byproducts and their prospective uses in dietary and agricultural settings.

Phosphorus (P) is an essential nutrient for plant growth, playing a crucial role in energy transfer, photosynthesis and root formation. The high phosphorus concentration in watermelon rinds (2,675.33 mg/kg) suggests their potential effectiveness as a soil amendment to enhance soil fertility. Phosphorus-rich fruit wastes, when utilised in soil, enhance nutrient availability, especially in phosphorus-deficient soils, hence fostering vigorous plant development and increased crop yields. Recent research indicates that organic amendments, such as fruit wastes, can gradually release phosphorus, providing a continuous nutrient supply to plants and minimising the risk of nutrient leaching [12]. Watermelon rinds represent a viable resource for sustainable agriculture, especially in areas with deficient soil phosphorus levels.

Potassium (K) is essential for plant vitality, governing water absorption, enzyme activation and general resilience to stress. The remarkably elevated potassium concentration in watermelon rinds (37,426 mg/kg) signifies its potential as a soil supplement to enhance soil potassium levels. Amendments rich in potassium enhance plant vitality, augment drought resilience and bolster disease resistance, rendering them essential for agricultural productivity in adverse conditions. Research indicates that the addition of potassium-rich organic materials to soil can improve soil structure and cation exchange capacity, hence promoting long-term soil fertility [13]. Consequently, watermelon rinds may function as a viable, environmentally sustainable source of potassium for agricultural systems.

Magnesium (Mg) is a fundamental element of chlorophyll, crucial for photosynthesis and facilitates enzyme activity and nutrient transfer in plants. Pineapple waste, containing a substantial magnesium concentration of 2,420.67 mg/kg, presents considerable promise as a soil supplement to rectify magnesium shortages in agricultural soils. Magnesium-enriched amendments can enhance photosynthetic efficiency, leading to improved plant growth and yield quality. Recent research indicates that organic magnesium sources, including fruit wastes, enhance soil mineral balance and alleviate shortages that hinder crop production [14]. Integrating pineapple waste into soil may enhance plant health and productivity in magnesium-deficient regions.

Calcium (Ca) is vital for plant cell wall formation, membrane stability and root development, making it indispensable for healthy plant growth. Orange peels, possessing a high calcium concentration (7,756.33 mg/kg), serve as an effective soil amendment for enhancing calcium levels, especially in acidic or calcium-deficient soils. Calcium supplements improve soil structure, diminish soil compaction and foster microbial activity, thus facilitating vigorous plant growth. Studies have shown that calcium-rich organic amendments can improve soil pH balance and nutrient uptake efficiency, contributing to sustainable crop production [15]. Orange peels, therefore, hold promise as a natural calcium source to enhance soil quality and plant resilience.

Table 1. The mean and ± S.E. of the chemical content of fruit wastes (mg/kg)

	Pineapple waste	Coconut flesh waste	Watermelon rinds	Orange peels
K	18560.00^{b} ± 544.50	7470.67^{c} ± 196.34	37426.67^{a} ± 459.94	10910.00^{c} ± 435.55
P	1592.00^{b} ± 27.50	1511.67^{d} ± 51.10	2675.33^{a} ± 28.49	934.03^{c} ± 13.88
Mg	2420.67^{a} ± 107.71	1023.60^{c} ± 68.87	1625.00^{b} ± 17.35	1144.33^{c} ± 2.40
Ca	2781.00^{c} ± 131.37	1212.67^{d} ± 6.94	3699.33^{b} ± 67.73	7756.00^{a} ± 76.20

Notes**:**
^{abc} Means with common superscripts are significantly different ($p<0.05$)
S.E. indicate standard error

3.2. pH

Table 2 indicates that orange peel powder is the most acidic of the fruit waste powders assessed, displaying the lowest pH value. The pH level of soil is a crucial determinant of plant growth, as it profoundly affects nutrient availability for absorption, as noted by [16].

An ideal soil pH guarantees the availability of key nutrients to plants, fostering robust growth [17-18]. Acidic soil conditions, presumably caused by extremely acidic materials like orange peels, can diminish nutrient availability through processes such as leaching, which washes nutrients away from the soil [19]. The elevated acidity of orange peels indicates their inappropriateness as soil amendments, since their use may decrease soil pH to levels detrimental to nutrient absorption and negatively impact plant growth [20].

Table 2. The pH value of fruit wastes

Fruit waste	pH
Pineapple	6.2
Coconut flesh	6.5
Watermelon rinds	6.3
Orange peels	5.5

4. Conclusion

Utilising the nutrient-dense characteristics of fruit waste can foster a circular economy, enhance sustainability and bolster resilience. This study analysed pineapple waste, coconut meat waste, watermelon rinds and orange peels, revealing significant nutritional disparities. Watermelon rinds possess superior nutritional content relative to other fruit byproducts. These findings may advance sustainable agriculture and waste management. This study demonstrates that fruit waste has high levels of nutrients, making it suitable for use in the planting process to enhance the soil's chemical qualities. This inclusion can mitigate environmental effects by decreasing the reliance on chemical fertilisers that significantly diminish soil fertility. Previous research indicates that the utilisation of fruit waste in both urban and rural environments constitutes a sustainable method for managing organic waste and effectively harnessing nutrients.

Future research may explore the many effects of incorporating fruit waste into soil as organic fertiliser to create tailored and optimal formulas for particular crops. Modifying soil nutrient composition according to fruit waste allows agricultural methods to be customised to meet the specific needs of different plant species, hence improving plant growth and overall crop output.

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Conflict of Interest

We declare no conflict regarding the publication of the study.

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