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Efficiency of Fruit and Vegetable Waste Compost Enrichment Using Poultry Manure and Wood Ash

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ABSTRACT

The growing generation of fruit and vegetable waste (FVW) presents considerable environmental challenges, while simultaneously offering a valuable opportunity for organic nutrient recycling. This study was carried out to assess the potential of enhancing fruit and vegetable waste compost through the addition of poultry manure and wood ash as nutrient amendments. Poultry manure and wood ash were added as enrichment materials to enhance the nutrient profile and physicochemical characteristics of the compost. The nutrient properties of the amendments were evaluated by measuring pH, electrical conductivity (EC), nitrogen (N), phosphorus (P), potassium (K), and organic carbon (OC). Poultry manure demonstrated higher levels of nitrogen (3.10%), phosphorus (2.333%), and organic carbon (26.333%), highlighting its effectiveness in promoting microbial activity, compost maturity, and soil fertility. Conversely, wood ash showed elevated pH (7.683), electrical conductivity (2.267 dS m^{-1}), and potassium content (3.133%), indicating its role in enhancing soil pH and potassium availability. The results indicate that poultry manure is a more effective amendment for improving the nutrient status of compost, while wood ash is an excellent source of potassium and a liming agent. The synergistic application of these amendments has the potential to yield nutrient-dense compost with well-balanced physicochemical properties, thereby supporting sustainable waste management, enhancing soil fertility, decreasing reliance on chemical fertilizers, and promoting environmentally sustainable agricultural practices.

Introduction

Large amounts of fruit and vegetable waste (FVW) are produced globally as a result of the fast expansion of agricultural markets, urbanization, and food processing businesses. The Food and Agriculture Organization (FAO) estimates that every year, 1.3 billion tonnes of food roughly one-third of all food produced for human consumption are lost or wasted. Almost 45–50% of the entire production of fruits and vegetables is wasted during harvesting, processing, transportation, marketing, and consumption, making them one of the foods with the greatest rates of waste. Fruit and vegetable waste accounts for 40–60% of municipal solid garbage in India, producing millions of tonnes of biodegradable residues annually. By transforming organic waste into a stable, nutrient-rich organic fertilizer that enhances soil fertility, soil structure, water-holding capacity, and microbial activity, composting has become one of the most ecofriendly and sustainable ways to recycle organic waste (Chakravarty *et al.,* 2021).

Despite the abundance of biodegradable organic matter found in fruit and vegetable waste, compost made exclusively from these materials frequently lacks appropriate amounts of vital plant nutrients, especially nitrogen (N), phosphorus (P), and potassium (K), which limits its agronomic utility. In order to improve compost quality, speed up decomposition, and increase nutrient availability, nutrient enrichment using appropriate organic and inorganic additives has emerged as a successful tactic (Sharma *et al.,* 2025).

Wood ash and poultry manure are two affordable, locally accessible agricultural by-products with unique nutritional properties that are frequently employed as fertilizer products. More than 25 million tonnes of poultry manure are produced worldwide each year as a result of poultry production, making it a plentiful source of organic nutrients.

In addition to helpful bacteria that speed up decomposition, lower the carbon-to-nitrogen ratio, boost microbial activity, and increase compost maturity and nutrient status, poultry manure usually contains 2.5–4.0% nitrogen, 2.0–3.0% phosphorus (P_2O_4), and 1.5–2.5% potassium (K_2O) (Sellami, *et al.,* 2008).

A by-product of burning biomass, wood ash is very rich in mineral elements; it contains roughly 3–10% potassium (K_2O), 20–35% calcium (CaO), 1–3% magnesium (MgO), and trace amounts of phosphorus and other micronutrients. Because of its alkaline pH (9–13), it helps improve nutrient availability, counteract compost acidity, and improve compost quality. Determining the proper application rates is crucial because excessive application might increase alkalinity and nitrogen loss through ammonia volatilization.

In terms of compost enrichment, these two amendments complement each other. While wood ash improves the chemical qualities of compost by adding potassium, calcium, and other mineral nutrients while controlling compost pH, poultry manure mostly helps the biological elements of composting by providing nutrients and encouraging microbial activity. Analyzing each of their effects separately yields important information on how well they work to improve the physicochemical characteristics and nutrient makeup of compost made from fruit and vegetable waste.

The present study was undertaken to evaluate the efficiency of enriching fruit and vegetable waste compost using poultry manure and wood ash as nutrient amendments. The objectives were to prepare compost from fruit and vegetable waste with the addition of these amendments, assess their effects on the physicochemical properties and nutrient composition of the compost, evaluate their influence on compost maturity and quality, and identify the most effective amendment for producing nutrient-rich compost suitable for sustainable soil fertility management and agricultural applications.

Materials and Methods

Experimental Site

The experiment was conducted under aerobic composting conditions at the composting unit in IIAT college farm. The composting unit was established in a well-drained, shaded area with adequate ventilation to minimize moisture loss and maintain uniform composting conditions. The average ambient temperature during the composting period ranged from 28 to 35°C.

Collection of Raw Materials

Fresh fruit and vegetable waste (FVW) consisting of banana peels, citrus peels, tomato residues, cabbage leaves, spinach leaves, and other market vegetable wastes was collected from the local vegetable market in Thuraiyur. Poultry manure was obtained from a nearby poultry farm, while wood ash was collected from biomass-burning units using untreated firewood. Dry crop residues (paddy straw) were used as a bulking agent to improve aeration and maintain the desired carbon-to-nitrogen (CN) ratio.

All non-biodegradable materials such as plastics, glass, and metals were removed manually before compost preparation. Fruit and vegetable wastes were chopped into 2-5 cm pieces to facilitate rapid decomposition.

Preparation of compost

Compost is prepared by collecting fresh fruit and vegetable waste and removing non-biodegradable materials. The waste is chopped into small pieces and mixed with dry leaves or crop residues to maintain a balanced carbon-to-nitrogen ratio. The mixture is placed in a compost pit, and moisture is maintained at about 50–60% (Sharma, A., *et al.,* 2024). The compost pile is turned regularly to ensure proper aeration and faster decomposition. To enhance the nutrient content and physic-chemical properties of compost, nutrients amendment like poultry manure and wood ash was incorporated into the fruit and vegetable waste compost to improve their nutrient level of compost. After 60–90 days, harvest the dark, earthy smell and crumbly natured mature compost and it is ready for use as organic manure in fertility management.

Results and Discussion

The study evaluated the nutrient content and chemical characteristics of poultry manure and wood ash enriched compost by examining major nutrient parameters: pH, Electrical Conductivity (EC), Nitrogen (N), Phosphorus (P), Potassium (K), and Organic Carbon (OC). This finding indicates show significant differences between the two organic amendments, highlighting that each substance offers unique advantages for managing soil fertility.

pH

The pH level of poultry manure was measured at 7.083, while wood ash exhibited a higher pH of 7.683. Both substances are categorized within the neutral to slightly alkaline pH, making them appropriate for agricultural applications. The elevated pH of wood ash is attributed to the presence of calcium carbonate, potassium carbonate, and various other alkaline minerals generated during the combustion of wood (Ibeto *et al.,* 2020). These elements contribute to enhance nutrient availability in acidic soils. Although poultry manure also raises soil pH, it does so to a lesser degree, as its nutrient profile is richer in organic matter compared to alkaline mineral salts.

Electrical Conductivity (EC)

Electrical Conductivity (EC) reflects the level of soluble salts in a material. Poultry manure has an EC of 1.477 dS m^{-1}, while wood ash has a higher EC of 2.267 dsm^{-1}. This elevated EC in wood ash indicates a higher concentration of soluble mineral salts, particularly potassium and calcium compounds (Ibeto *et al.,* 2020). While these salts are beneficial for plant nutrition, excessive use can lead to increased soil salinity. Thus, it is essential to apply wood ash in recommended amounts to prevent salt stress in sensitive crops.

Organic carbon

The enrichment treatments had a significant influence on the compost's organic carbon content using Completely Randomised Design (CRD). ANOVA table showed a significant treatment effect ($F = 3561.45$, $P < 0.01$), indicating that the enrichment materials significantly impacted the compost's organic carbon content. The coefficient of variation (CV) was 1.04%, indicating good experimental precision, and the critical difference (CD) at the 5% level was 0.382, confirming that the differences in treatment means were statistically significant. Among the treatments, poultry manure-enriched compost (Treatment 2) had the highest organic carbon content (26.33%), followed by wood ash-enriched compost (Treatment 3) with 15.10%.The fruit and vegetable waste compost without enrichment (Treatment 1) had the lowest organic carbon content (14.40%), indicating significant differences among the three treatments. The poultry manure enriched compost had significantly higher organic carbon content, possibly due to improved organic matter stabilisation and reduced carbon losses during the composting process. Although wood ash enrichment increased organic carbon content relative to the control, it remained significantly lower than that of poultry manure enriched compost, probably due to increased microbial activity and faster decomposition caused by the higher nitrogen concentration (Chuenchart *et al.,* 2020). These data show that wood ash enrichment significantly increased compost's organic carbon status, increasing its potential to improve soil fertility, soil structure, microbial activity, and long-term nutrient availability.

Nitrogen

The enrichment treatments had a significant effect on the nitrogen content of the compost, as indicated by the ANOVA table ($F = 255.78$, $P < 0.01$). The experimental error was low, with a coefficient of variation (CV) of 6.60%, and the critical difference (CD) at the 5% level was 0.236, indicating significant differences between treatment means. Among the treatments, poultry manure-enriched compost (Treatment 2) had the highest nitrogen content (3.1). In contrast, wood ash-enriched compost (Treatment 3) had 1.27% nitrogen, while fruit and vegetable waste compost (Treatment 1) had the lowest nitrogen content (1.10%). Both Treatments 1 and 3, indicating that their nitrogen contents were statistically on par with each other but significantly lower than that of Treatment 2. The significantly high nitrogen content in poultry manure-enriched compost could be due to improved nitrogen conservation during composting and lower volatilization losses under favorable composting conditions. The alkaline compounds found in poultry manure-enriched compost may have improved nutritional stability and facilitated effective microbial translation of organic nitrogen into stable forms, resulting in increased nitrogen retention (Chuenchart *et al.,* 2020). Although wood ash compost is widely regarded as a high-nitrogen source, its nitrogen level in the final compost was statistically equal to that of fruit and vegetable waste compost, probably due to increased nitrogen losses through ammonia volatilization during decomposition. The significant increase in nitrogen content found with poultry manure enrichment suggests that it is helpful in improving the nutrient status of compost.

Phosphorus

The analysis of variance showed a highly significant treatment effect ($F = 113.32$, $P < 0.01$), indicating that the enrichment materials had significant effects on the compost's phosphorus content. The critical difference (CD) at the 5% level was 0.327, showing substantial differences between the treatment means, while the coefficient of variation (CV) was 13.39%, suggesting acceptable experimental precision. The treatment with the highest phosphorus concentration (2.33%) was the compost supplemented with poultry manure (Treatment 2) (Rizzo *et al.,* 2015). Fruit and vegetable waste compost without enrichment (Treatment 1) had the lowest phosphorus content (0.30%), while wood ash-enriched compost (Treatment 3) came in second with 1.10%.

All three treatments showed significant differences from each other, according to the different enrichment test. The enrichment process, which improved phosphorus retention and mineralization during composting, may be responsible for the significantly greater phosphorus content found in the wood ash-enriched compost. Significant amounts of mineral ash and alkaline components found in wood ash may reduce phosphorus fixation and increase its availability in the final compost. By contrast, the phosphorus content of the poultry manure-enriched compost was higher than that of the unenriched compost due to the release of organically bound phosphorus through microbial decomposition (Ibeto *et al.,* 2020). However, the level of phosphorus remained significantly lower than that of the wood ash-enriched compost. The lack of additional nutrient sources and the low intrinsic phosphorus content of the raw materials are indicated by the fruit and vegetable waste compost's lowest phosphorus content without enrichment.

Potassium

Under the Completely Randomized Design (CRD), the enrichment treatments had a significant impact on the compost's potassium content. The enrichment materials had a significant impact on potassium content, according to the analysis of variance (ANOVA), which showed a highly significant treatment effect ($F = 79.36$, $P < 0.01$). Significant differences between the treatment means were confirmed by the critical difference (CD) at the 5% level of 0.376 and the coefficient of variation (CV) of 8.21%. Poultry manure-enriched compost (Treatment 2) had a potassium content of 2.63%, while wood ash-enriched compost (Treatment 3) had the highest potassium content (3.13%). The compost made from fruit and vegetable waste that was not enriched (Treatment 1) had the lowest potassium content (1.23%). All three treatments differed significantly from one another, according to the multiple comparison tests. The increased amount of potassium from wood ash and its quick mineralization during composting may be the cause of the noticeably higher potassium content in the wood ash-enriched compost, which increases the amount of soluble potassium released into the final compost (Ibeto *et al.,* 2020).

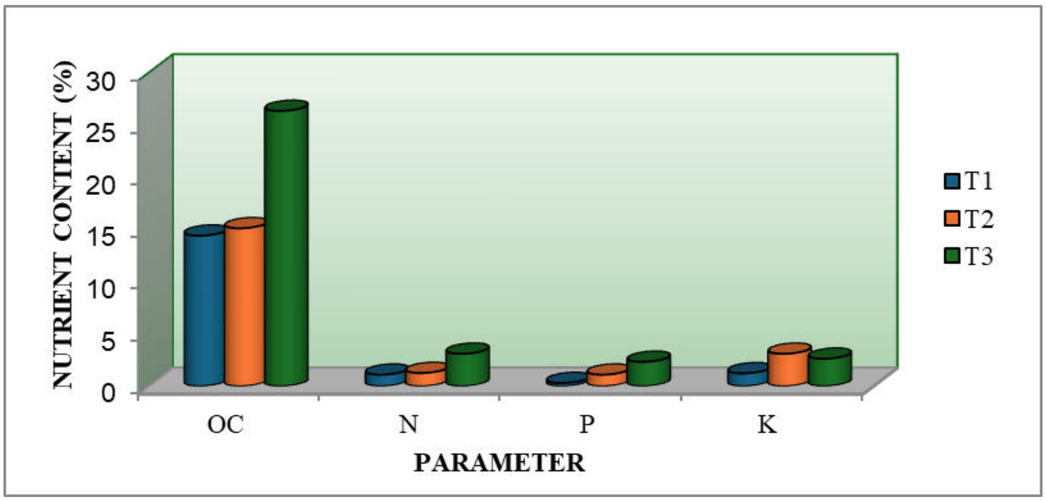
Because it is not incorporated into complex organic compounds, potassium is easily accessible in mature compost and is relatively mobile during the decomposition process. Even though poultry manure is known to be a rich source of potassium and has a much higher potassium content than the FVW compost, its concentration was still lower than that of the poultry manure-enriched compost in the current study. Due to the lack of external nutrient supplementation and the limited potassium reserve in the raw materials, the fruit and vegetable waste compost with the lowest potassium content was found without enrichment.

Table.1 Efficiency of fruit and vegetable waste compost using different nutrient amendments

S. No	Parameter	Fruit and vegetable waste compost (without enrichment)	Poultry manure enriched compost	Wood ash enriched compost
1.	pH	6.8	7.6	7.08
2.	EC (dS m^{-1})	1.27	2.26	1.47
3.	Organic carbon	14.4	15.1	26.33
4.	Nitrogen (%)	1.1	1.26	3.1
5.	Phosphorus (%)	0.3	1.1	2.33
6.	Potassium (%)	1.23	3.1	2.63

(T1- control (FVW without enrichment), T2- FVW compost enriched with poultry manure, T3- FVW compost enriched with wood ash)

Fig.1 Nutrient status of fruit and vegetable compost with nutrient enrichment



(T1- control (FVW without enrichment), T2- FVW compost enriched with poultry manure, T3- FVW compost enriched with wood ash)

The results indicate that both treatments positively influence soil characteristics, but their effects differ. Poultry manure is a better source of essential nutrients such as nitrogen, phosphorus, and organic carbon, making it suitable for improving soil fertility and crop growth.

In contrast, wood ash is effective in raising soil pH and supplying potassium, which can help correct acidic soils. Therefore, the choice of treatment depends on the soil's nutrient requirements. Poultry manure is recommended for improving overall soil health, while wood ash is more suitable for enhancing soil pH and potassium availability.

The present study concludes that poultry manure is the better soil amendment, according to the physicochemical characterisation, because of its higher organic matter content and better nutrient composition, which enhance soil fertility and nutrient availability. On the other hand, wood ash mostly acts as a soil conditioner by raising the pH of the soil and providing potassium, which makes it very helpful for improving acidic soils. Wood ash is better used as a supplemental amendment for particular soil management goals, while poultry manure showed higher potential as a primary organic amendment based on the characteristics assessed in this study.

Future studies should concentrate on confirming these results in the field and assessing the long-term impacts of repeated applications on crop productivity, nutrient dynamics, soil physicochemical and biological characteristics, and environmental quality across various soil types and cropping systems.

Author Contributions

Kaviya Shanmugam: Investigation, formal analysis, writing—original draft. B. Aravind Raj: Validation, methodology, writing—reviewing. G. Ashwin:—Formal analysis, writing—review and editing. M. Gomathi Sankar: Investigation, writing—reviewing. M. Iyyanar: Resources, investigation writing—reviewing. M. Pradeepan: Validation, formal analysis, writing—reviewing. A. Shahid Afridi: Conceptualization, methodology, data curation, supervision, writing—reviewing the final version of the manuscript. M. Subash: Investigation, formal analysis, writing—original draft. P. Vinoth: Validation, methodology, writing—reviewing. D. Vishwa:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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