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# Characterization and Utilization of Paper and Fruit Peel Waste for Biofertilizer Production

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## ABSTRACT

This study investigated the conversion of institutional paper waste and fruit peels into biofertilizers to enhance the growth and yield of economically significant crops. Pre-treated paper waste underwent vermicomposting with farmyard manure and the earthworm species *Eisenia fetida*. The resulting compost was rigorously analyzed for macro and micronutrient content, earthworm mortality rates and heavy metal presence. The optimal compost formulation consisted of 2 kg of paper waste, 1 kg of cow dung and 1 kg of cardboard with 3 replicates, yielding 3.1 kg of nutrientrich vermicompost (N: 0.71%, P: 0.27%, K: 1.26%) per 12 kg of initial waste, all free of heavy metals. Fruit peel biofertilizers from oranges and sweet limes were quantified and applied in plant growth experiments, which significantly enhanced soil nutrient levels. Specifically, mustard responded positively to sweet lime peel at 5g/100 ml and orange peel at 1g/100 ml, while wheat benefited from orange peel at 1g/100 ml and sweet lime at 5g/100 ml. Fenugreek showed improved nutrient uptake with orange peel at 4g/100 ml and sweet lime at 5g/100 ml. The study identified 5g/100 ml as the most effective concentration for enhancing nutrient content across all tested crops, highlighting the potential of these biofertilizers to contribute essential nutrients for sustainable agriculture.

**Key words:** Biofertilizers, institutional paper waste, fruit peels, vermicomposting, nutrient analysis

## INTRODUCTION

This study presents a novel approach to in-house solid waste management, emphasizing the role of educational institutions and stakeholders in promoting sustainable practices (Elsheekh *et al.*, 2021; Sharma *et al.*, 2021; Abubakar *et al.*, 2022;). Effective waste management is crucial for environmental preservation, as methods like landfilling and incineration pose significant risks, while recycling can be resource-intensive, particularly in densely populated developing countries. Our study investigated the potential of vermicomposting as an eco-friendly solution for managing paper waste, utilizing earthworms to convert it into nutrient-rich vermicompost, thereby enhancing soil fertility and reducing reliance on chemical fertilizers (Lirikum *et al.*, 2022). Additionally, our findings explored the use of fruit peels, rich in essential nutrients, as biofertilizers to further support sustainable agricultural practices ( Rather *et al.*, 2023). By recycling these organic materials, the soil health can be improved. It can mitigate environmental impact and provide cost-effective alternatives to synthetic fertilizers, ultimately contributing to soil fertility and environmental conservation ( Atta *et al.*, 2020; Bishnoi *et al.*, 2023; Devi *et al.*, 2023).

## MATERIALS AND METHODS

At the C. G. Bhakta Institute of Biotechnology, a pilot study on paper waste decomposition through vermicomposting was conducted. Solid waste was daily collected, sorted into organic and non-organic categories, with organic waste designated for vermicomposting (Manohar *et al.*, 2016; Yatoo *et al.*, 2020). Two experimental setups were created: Setup 1 (1 kg cow dung, 2 kg paper waste) and Setup 2 (1 kg cow dung, 2 kg paper waste, 1 kg cardboard), each with a control and three replicates. The process utilized *Eisenia fetida* earthworms to enhance decomposition within dedicated compost vessels (Mpuangnan *et al.*, 2023). Each

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setup involved layering soil bedding, cow dung, pre-treated paper waste (soaked for 15 days), and in Setup 2, additional pre-conditioned cardboard. The composting process included mesophilic, thermophilic and maturation phases, monitored for worm activity, moisture and pH over 50 days. After harvesting, the vermicompost was sieved and analyzed for nitrogen, phosphorus, potassium, micronutrients and heavy metals. Pot assays were conducted using fenugreek, wheat and mustard to evaluate agricultural potential (Mirzaei, 2022).

Fruit peels were prepared for the experiment by collecting fresh sweet lime and orange peels from the university juice centre followed by washing, air-drying and finely grinding them. The resulting powder was mixed with distilled water to create various liquid extract concentrations. Soil in plantation pots was treated with these extracts, while control pots received only distilled water. Fenugreek, mustard and wheat seeds were planted in both control and treated pots, with multiple replicates (Bari, 2019). Different formulations (1 to 5 grams of peel powder per 100 ml of distilled water) were applied to the soil, followed by macronutrient testing and growth assessment. Soil samples were analyzed for NPK content and plant growth parameters like height and biomass were recorded. Results showed varied effects of fruit peel application on plant species, highlighting the complexities of plant-soil interactions and the importance of tailored organic waste recycling strategies.

## RESULTS AND DISCUSSION

At the C. G. Bhakta Institute of Biotechnology, solid waste was measured daily using a hanging scale. Waste generation was influenced by departmental population and seasonal factors, averaging 47.32 kg/day during the first study period (P1) and 33.09 kg/day during the second study period (P2). Waste from sampling sites in P1 was distributed as follows: SCS-1 (25.2 kg/day, 53.25%), SCS-2 (14.5 kg/day, 30.64%) and SCS-3 (7.62 kg/day, 16.10%). In P2, the distribution was: SCS-1 (16.97 kg/day, 51.28%), SCS-2 (10.2 kg/day, 30.82%) and SCS-3 (5.92 kg/day, 17.89%). Monthly totals were 1198 kg in P1 and 840 kg in P2, with SCS-1, SCS-2 and SCS-3 contributing 51.33, 30.39 and 18.31% of P1's waste, and 49.63, 30.84 and 19.52% of P2's waste, respectively. Waste composition consisted of 66% paper and cardboard, 24% plastic, 4% glass and 6% other materials, with approximately 65% being potentially compostable. Table 1 presents differences between Setup 1 (9 kg waste) and Setup 2 (12 kg waste). Setup 1.4 exhibited higher nitrogen levels, while Setup 2.2 demonstrated peak nitrogen content for its setup. Additionally, Setup 1.4 excelled in phosphorus, whereas Setup 2.2 led in phosphorus for Setup 2.

**Table 1.** Comparative analysis of treatment, control, mortality rate of worms and macro and micronutrient content in both the setups

| | MWO (Nos.) | IMO (Nos.) | CO (Nos.) | TV (kg) | N (%) | P (%) | K (%) | Fe (ppm) | Zn (ppm) | Cu (ppm) | Mn (ppm) | Na (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Setup 1** | | | | | | | | | | | | |
| C | 12 | 74 | 98 | 1.90 | 0.20 | 0.12 | 0.65 | 4.84 | 0.30 | 0.45 | 4.66 | 18.12 |
| CS 1.1 | 20 | 113 | 178 | 1.78 | 0.82 | 0. 20 | 0.99 | 16.67 | 1.30 | 4.23 | 12.07 | 21.38 |
| CS 1.2 | 28 | 185 | 92 | 2.10 | 0.96 | 0.27 | 1.20 | 10.23 | 1.21 | 3.54 | 9.34 | 19.21 |
| CS 1.3 | 54 | 107 | 183 | 1.80 | 0.61 | 0.12 | 0.85 | 15.10 | 1.29 | 3.73 | 10.56 | 21.23 |
| CS 1.4 | 25 | 79 | 162 | 2.20 | 0.52 | 0.38 | 0.98 | 16.44 | 1.44 | 5.81 | 11.21 | 22.65 |
| CS 1.5 | 34 | 146 | 127 | 1.89 | 0.65 | 0.16 | 1.09 | 15.87 | 1.30 | 4.76 | 10.11 | 19.31 |
| **Setup 2** | | | | | | | | | | | | |
| C | 8 | 64 | 56 | 2.80 | 0.87 | 0.31 | 0.87 | 6.37 | 0.50 | 0.81 | 6.78 | 20.13 |
| CS 2.1 | 67 | 55 | 197 | 3.10 | 0.71 | 0.27 | 1.26 | 19.34 | 1.54 | 6.81 | 16.43 | 23.56 |
| CS 2.2 | 24 | 53 | 177 | 2.92 | 0.94 | 0.32 | 1.10 | 23.87 | 2.11 | 6.87 | 18.12 | 24.78 |
| CS 2.3 | 25 | 85 | 192 | 2.71 | 0.84 | 0.15 | 0.98 | 19.45 | 1.61 | 7.32 | 16.78 | 24.20 |
| CS 2.4 | 20 | 83 | 183 | 3.20 | 0.59 | 0.24 | 1.12 | 20.56 | 1.22 | 7.44 | 17.66 | 22.14 |
| CS 2.5 | 34 | 59 | 172 | 2.90 | 0.62 | 0.17 | 1.20 | 25.87 | 1.80 | 6.34 | 17.54 | 22.67 |

In each sub-set in set up 1, a total of 9 kg waste and in set up 2, a total of 12 kg waste was utilized, whereas in all subsets 25 mature clitellate worms were employed. C: Control, CS: Compost Set-up (each with 3 replicates), MWO: Mature worms obtained, IMO: Immature worms obtained, CO: Cocoons obtained, TV: Total vermicompost (in kg), N: Nitrogen, P: Phosphorus, K: Potassium, Fe: Ferrous, Zn: Zinc, Cu: Copper,Mn: Manganese and Na: Sodium.

Potassium concentrations were highest in Setup 1.2 and Setup 2.1. Notably, both setups recorded no worm mortality, indicating a suitable environment for vermicomposting. The compost from both setups contained enhanced macro and micronutrients compared to the control, highlighting the effectiveness of vermicomposting. This study primarily focused on utilizing paper waste, a major component of institutional waste, to create vermicompost using *Eisenia fetida* and farm yard manure (FYM) as primary and secondary food sources, respectively. Previous studies by Manohar *et al*. (2016) had shown that pre-decomposed materials did not lead to worm mortality, emphasizing the importance of pre-composting in maintaining earthworm viability. Our findings, consistent with those of Manohar *et al*. (2016) which involved a 15-day pre-treatment for paper waste. Initially, 20 earthworms were introduced per setup, increasing to 67 mature worms, 55 immature worms and 197 cocoons after 60 days. Our approach differed by incorporating paper, cardboard and FYM, supplemented with dried leaves to achieve an optimal carbon-to-nitrogen (C/N) ratio conducive to earthworm reproduction. Nutrient analysis showed significant concentrations of nitrogen (0.96%), phosphorus (0.38%) and potassium (1.26%) after 50 days of vermicomposting, corresponding to the amount of reduced waste. This aligns with findings by Manohar*et al.* (2016) where varying initial waste concentrations affected final macronutrient levels. Our study, utilizing three replicates per setup, enhanced statistical robustness compared to previous studies with no replications. Heavy metal analysis indicated negligible levels of contaminants as shown in Table 2, affirming the safety and efficacy of the vermicompost for agricultural applications. Comparative analysis of orange and sweet lime peels on fenugreek, wheat and mustard plants indicated significant improvements in growth metrics and soil nutrient content as shown in Tables 3, 4 and 5. Nutrient analysis of fenugreek (*Trigonella foenum-graecum* L.), wheat (*Triticum aestivum*) and mustard (*Brassica juncea*) treated with citrus peel formulations showed significant enhancements: nitrogen levels were 190.70 kg/ha for fenugreek, 192.70 kg/ha for wheat and 200.3 kg/ha for mustard; phosphorus levels were 38, 39 and 47 kg/ha, respectively; and potassium levels were 304, 302 and 317 kg/ha, respectively. The application of 5 g of citrus peel extract per 100 ml notably increased nutrient content, reflecting enhanced nitrogen fixation and nutrient uptake, particularly in mustard, which demonstrated superior nutrient absorption and overall growth response. These

**Table 2.** Heavy metal analysis of vermicompost manure using ICP spectroscopy (inductively coupled plasma) - sample CS 2.1 (sample of compost setup 2.1 was selected since it exhibited a satisfactory quantity of both macro and micronutrients and was chosen as a representative sample)

| Heavy metal | Amount (ppm) | Heavy metal content |
|---|---|---|
| Cadmium (Cd) | Not detected | 5.00 |
| Chromium (Cr) | 19.68 | 50.00 |
| Nickel (Ni) | 11.47 | 50.00 |
| Lead (Pb) | 3.42 | 100.00 |

**Table 3.** Comparative analysis of orange and sweet lime peels on fenugreek plant growth and soil nutrient content

| Fruit peel | FC (g/100 ml D/W) | Stem girth | Comparative leaf size | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|---|---|---|
| Orange (*Citrus sinenses*) | Control | Moderate | Shrivel | 182.10 | 27.00 | 231 |
| | 1 | Moderate | Shrivel | 205.00 | 34.00 | 295 |
| | 2 | Moderate | Small | 196.00 | 32.00 | 234 |
| | 3 | Sturdy | Small | 193.00 | 30.00 | 298 |
| | 4 | Sturdy | Normal | 202.60 | 36.00 | 301 |
| | 5 | Sturdy | Normal | 198.50 | 42.00 | 298 |
| Sweet lime (*Citrus limetta*) | Control | Moderate | Shrivel | 182.10 | 27.00 | 231 |
| | 1 | Moderate | Shrivel | 186.80 | 24.00 | 246 |
| | 2 | Moderate | Shrivel | 138.20 | 27.90 | 256 |
| | 3 | Sturdy | Normal | 167.80 | 30.00 | 211 |
| | 4 | Sturdy | Normal | 188.40 | 44.00 | 300 |
| | 5 | Sturdy | Normal | 190.70 | 38.00 | 304 |

FC: Fruit peel concentration, N: Nitrogen, P: Phosphorus and K: Potassium.

**Table 4.** Comparative analysis of orange and sweet lime peels on wheat plant growth and soil nutrient content

| Fruit peel | FC (g/100 ml D/W) | Comparative leaf size | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|---|---|
| Orange (*Citrus sinenses*) | Control | Normal | 188.6 | 28 | 238 |
| | 1 | Small | 204.0 | 32 | 298 |
| | 2 | Small | 191.7 | 36 | 286 |
| | 3 | Normal | 198.1 | 30 | 298 |
| | 4 | Normal | 194.4 | 42 | 300 |
| | 5 | Normal | 169.5 | 34 | 298 |
| Sweet lime (*Citrus limetta*) | Control | Normal | 188.6 | 28 | 238 |
| | 1 | Normal | 188.6 | 25 | 242 |
| | 2 | Small | 128.2 | 30 | 256 |
| | 3 | Small | 163.2 | 44 | 210 |
| | 4 | Normal | 188.6 | 28 | 299 |
| | 5 | Normal | 192.7 | 39 | 302 |

FC: Fruit peel concentration, N: Nitrogen, P: Phosphorus and K: Potassium.

**Table 5.** Comparative analysis of orange and sweet lime peels on mustard plant growth and soil nutrient content

| Fruit peel | FC (g/100 ml D/W) | Stem girth | Comparative leaf size | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|---|---|---|
| Orange (*Citrus sinenses*) | Control | Sturdy | Small | 198.5 | 23.0 | 210 |
| | 1 | Moderate | Small | 204.0 | 29.0 | 299 |
| | 2 | Sturdy | Normal | 209.0 | 36.0 | 265 |
| | 3 | Moderate | Normal | 204.3 | 38.0 | 287 |
| | 4 | Moderate | Normal | 210.0 | 35.9 | 230 |
| | 5 | Moderate | Normal | 210.3 | 39.0 | 298 |
| Sweet lime (*Citrus limetta*) | Control | Moderate | Small | 198.5 | 23 | 210 |
| | 1 | Moderate | Small | 189.0 | 25 | 255 |
| | 2 | Sturdy | Normal | 178.0 | 32 | 298 |
| | 3 | Sturdy | Normal | 199.0 | 38 | 302 |
| | 4 | Sturdy | Normal | 201.0 | 33 | 310 |
| | 5 | Sturdy | Normal | 200.3 | 47 | 317 |

FC: Fruit peel concentration, N: Nitrogen, P: Phosphorus and K: Potassium.

findings highlight the efficacy of citrus peel biofertilizers in improving soil fertility and plant health, presenting a sustainable alternative to chemical fertilizers. Overall, this study underscored the potential of utilizing agricultural waste as an eco-friendly approach to enhance crop productivity and promote sustainable agricultural practices.

## CONCLUSION

In conclusion, this study effectively addressed institutional waste, particularly paper and fruit peel waste, by converting them into valuable resources through vermicomposting and fruit peel formulations. Our experimental setups demonstrated the feasibility of this approach, with no heavy metals detected in the resulting compost, highlighting its safety for widespread use. The observed increase in worm reproduction further supports the sustainability of this method. By maintaining optimal pH and moisture over 50 days, it ensured high-quality biofertilizer production. The notable increases in nitrogen, phosphorus and potassium in fenugreek, wheat and mustard suggested potential for commercial applications. Our research recommends further field trials using Split Plot Design (SPD) or Pooled Split Plot Design (PSPD) to validate these findings and enhance sustainable agricultural practices. This research contributes valuable insights into natural fertilizers and innovative waste management solutions.

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