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# Transforming Canteen Waste Into Biofertilizer: A Sustainable Approach To Waste Reduction

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**Abstract**
*The generation of substantial dry kitchen waste in canteens of educational institutions presents challenges for disposal and environmental concerns. However, it also suggests the potential to repurpose this waste into valuable resources for creating useful, recycled products. This study investigates the conversion of college kitchen dry waste into plant biofertilizer on campus, highlighting its role in sustainable waste reduction. The kitchen dry waste utilized includes vegetable peels, fruit peels, used tea powder, and eggshells. By diverting biodegradable waste from landfills, greenhouse gas emissions are significantly reduced, aiding in carbon restoration and climate change mitigation. The research explores straightforward biofertilizer-making techniques implemented on college campuses and quantifies the sustainable environmental impact achieved through waste reduction.*

***Keywords***: *kitchen waste; biofertilizer; environmental impact; lifecycle assessment.*

## 1. INTRODUCTION

Soil is the womb of all flora and vegetation worldwide. Soil is the basis of life on Earth, providing the necessary resources for vegetation. Soil provides the physical anchors, nutrients, and water needed by plants to grow and thrive. Plants extract nutrients from the soil, and hence, the basic nutrients need to be replenished regularly over time. Fertilisers boost the reserves of elements essential for the healthy growth and development of plants. Fourteen mineral nutrients are essential to plant growth. Plant yields decrease if the soil does not have sufficient levels of each nutrient. The three most important macronutrients to manage are the primary macronutrients nitrogen (N), phosphorus (P), and potassium (K), collectively known as NPK (Pandey, 2018). Other vital nutrients include calcium, magnesium, and sulphur, along with micronutrients such as iron, copper, and zinc (Pandey, 2018).

Although both conventional and organic fertilisers add the required nutrients to the soil, organic fertilisers differ because they are derived from natural sources as opposed to being synthetically manufactured. Manure is organic matter that is used as an organic fertiliser or bio-fertiliser in agriculture. It is a natural form of fertiliser and is cost-effective. Kitchen waste is a unique organic soil feeder as it is the main source of organic matter. Kitchen waste also has a high biodegradability rate. Organic fertilizers are produced through composting and fermentation processes, both of which require ample space and involve microbial activity over time. However, the composting process can attract pests, emit strong odours, and demand significant energy for aeration and turning. Fermentation, particularly anaerobic digestion, can generate methane gas, a potent greenhouse gas, and may not significantly reduce the volume of organic waste (Jędrczak, 2018). In this study, we focused on a college canteen situated in an urban residential area, where space for fermentation and composting of generated waste is limited. Additionally, storing the waste for extended periods made the processes challenging. To address these issues, we utilized dry kitchen waste that was ground and employed bio-fertilizer to enhance soil fertility.

While in the college canteen, we observed a notable amount of dry waste being produced, alongside waste from cooked and processed foods. This dry waste, generated in large quantities, is merely thrown away as solid waste. A significant portion of this dry waste comes from activities like cutting vegetables, peeling fruits, and egg counters. Moreover, the tea and coffee counters add considerably to the dry kitchen waste with their used tea leaves and coffee grounds. There has been extensive research on the use of cooked food waste for producing bio-fertilizers (Mahish, 2024; Sharma, 2023).

Numerous studies have explored the use of dry kitchen waste as a bio-fertilizer (Khanyile, 2024; Ma'mor, 2023), (Sadiya, 2020). The literature reveals that fruit peels are utilized to create both acidic and alkaline nutrient mixtures for soil (Jariwala, 2016), (Kadam, 2022). Although banana peels are often discarded, they are rich in potassium, while orange peels serve as a good source of nitrogen. Eggshells are abundant in calcium and phosphorus, and potassium is also present in fruit peels (Ma'mor, 2023).

Reports indicate that a blend of vegetable and fruit peels can be used as a bio-fertilizer in powdered form, water extracts, or through anaerobic decomposition (Sadiya, 2020), (Ramamoorthy, 2024). Since both vegetable and fruit peels are excellent sources of N, K, and P, and eggshells are rich in Ca, we created a mixture of vegetable peels, fruit peels, used tea powder, and eggshells to assess the combined effect of this dry mixture on soil fertility.

The present study also quantifies the sustainable environmental impact generated through waste reduction by Lifecycle assessment (LCA) methodology) (Zhang, 2021). LCA gives a framework to evaluate holistic environmental impacts of any product/process. (Adhikari, 2024). Food waste can be disposed of in several ways (Prepilková, 2023)

a) Landfilling - Food waste is sent to landfill sites where it decomposes anaerobically, generating methane.
b) Composting - Food waste is broken down by microorganisms to produce nutrient-rich additives for the soil.
c) Anaerobic digestion - Food waste is processed in oxygen-free conditions by microorganisms to produce biogas, a mixture of methane and carbon dioxide.
d) Recycling into animal feed - Food waste is processed and used as animal feed if deemed safe.
e) Recycling into biofertilizer - Food waste is processed to produce biofertilizer, enhancing soil fertility.

Landfilling is a common practice in most regions of our country, resulting in significant environmental impacts due to greenhouse gas emissions. In contrast, the other disposal methods aforementioned offer substantial environmental benefits by reducing greenhouse gas emissions (Tong, 2018). This study aims to compare and analyze the environmental impact of disposing of dry kitchen waste through landfilling versus recycling it into biofertilizer.

## 2. MATERIALS & METHODS

**Collection and processing of soil sample:** The soil was collected from a farmyard in Lonavala, Pune district. The collected soil was stored in an open container and sun dried to remove any moisture. The soil contained pebbles, root, rock pieces, and so the soil was sieved by using 8 mm sieve to remove the pebbles, root, and rock pieces. The collected soil was properly stored.

**Collection of kitchen waste and preparation of bio-fertilizer:**

The ingredients selected for making the bio fertilizer from kitchen waste included onion peels, garlic peels, banana peels, orange peels, eggshells, and used tea powder. These peels, along with the used tea powder and empty eggshells, were gathered from the daily kitchen waste at the college. The banana, orange, onion, and garlic peels were thoroughly sun-dried for two days. The eggshells were cleaned with soapy water before being sun-dried, while the used tea powder was washed thoroughly to remove any sugar traces and then sun-dried until all moisture had evaporated. Once dried, each component was individually ground into a powder using a blender or food processor, then sieved and stored at room temperature. The bio fertilizer was prepared by mixing equal parts by weight of the banana peel, orange peel, onion peel, garlic peel, eggshell, and tea powder. This bio fertilizer mixture was then stored at room temperature.

**Experimental Plant setups:**

To study the efficiency of the prepared bio fertilizer, two plants were selected – sprouts of moong and Chana. A general guideline for adding manure to soil for fertility is to aim for about 5% organic matter in the soil. (https://anrcatalog.ucanr.edu/)

In our study, we utilized 100 g of soil sample for each setup. To evaluate the performance of our biofertilizer against commercially available compost, we applied a total of 2% by weight relative to the soil for both the biofertilizer and the compost. Initially, we introduced 1% of the biofertilizer, and after one week, we added another 1% to replenish the nutrients consumed during germination; the same procedure was followed for the commercial compost. We planted 15 seeds of each type (moong and Chana) in separate planters and monitored their growth over two weeks. Additionally, we included a setup with 5% biofertilizer and a control setup containing only the soil sample as part of the study.

**Elemental Analysis Method:**

The elemental analysis of N (nitrogen), K (potassium), and P (phosphorus) was performed on different soil samples used in the setups. Nitrogen analysis was done by Kjeldahl's method) (Nelson, 1980), Phosphorus was analyzed by spectrophotometric method (Shyla, 2011) and Potassium by flame photometry (Kamble, 2021).

**Scenarios developed for the sustainability study:**

Two scenarios were created (Figure 1) to identify the best solution for dry kitchen waste disposal from an environmental impact study perspective.

Scenario 1: disposal of the dry kitchen waste to the nearest landfill. This scenario consists of two stages. Stage 1 is collecting and transporting of dry kitchen waste from college to nearest landfill, and stage 2 would be degradation of dry kitchen waste in the landfill. The nearest landfill from NMIMS University campus would be the Deonar landfill at a distance of 19.2 km.

Scenario 2: converting dry kitchen waste to biofertilizer. This scenario does not require any transportation. This scenario also consists of two steps. Step 1 is sun drying the dry kitchen waste for 48 h. Step 2 is grinding and mixing the dried kitchen waste into a powdered form.

**Life cycle assessment method:**

**Goal identification, system boundary, and functional unit:**

The aim of this life cycle assessment study (Adhikari, 2024) is to identify which of the two scenarios mentioned above is more sustainable and has the least environmental impact. The system boundary for this study is defined as cradle to gate, as illustrated in Figure 1. Both scenarios serve the purpose of disposing of dry kitchen waste. The functional unit for this study is 1,000 kg of dry kitchen waste.

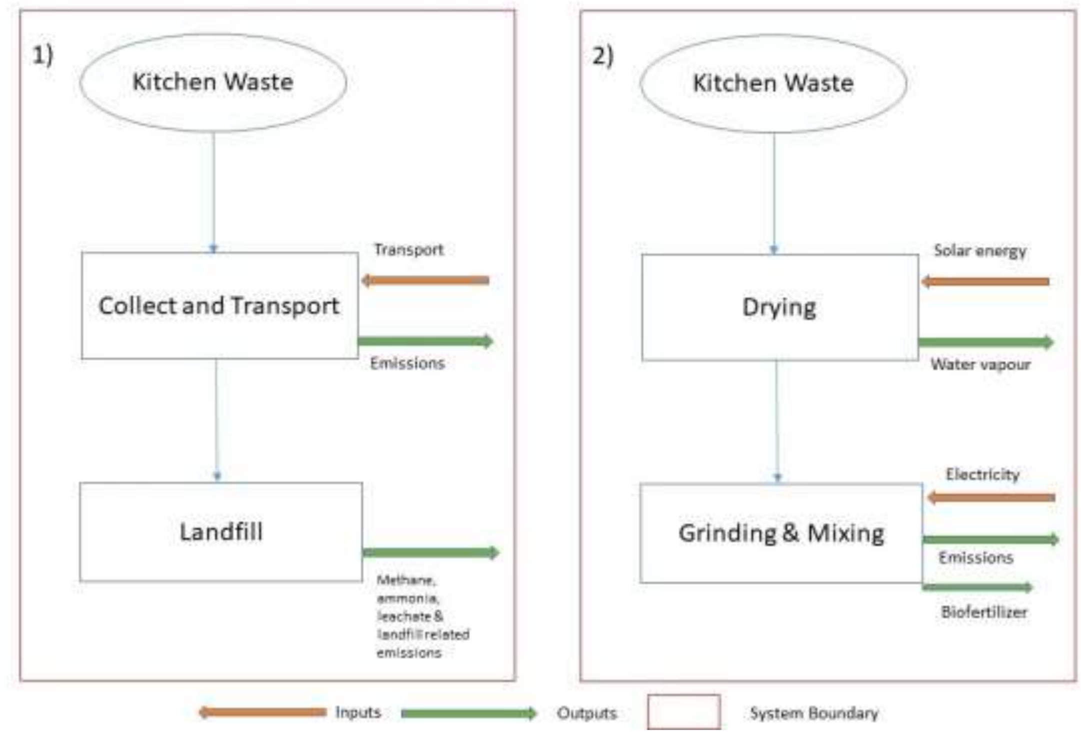


**Figure 1**: System boundry diagram of scenario-1 and scenario-2

**Life cycle inventory (LCI):**

For scenario 1, primary data (Adhikari, 2024) was collected from college canteen personnel about the amount and types of kitchen waste and the disposal process to the municipality. Primary data used for scenario 2 was based on the experiments related to the biofertilizer. Additionally, data from the ecoinvent 3.1 database was used to get the secondary data for the lifecycle assessment study.

LCI for dry kitchen waste disposal by landfill process (Scenario 1):
1000 kg of kitchen waste, and 1.9 x$10^4$ kg x km of transportation was used as the input. The outputs used in the study were ammonia, carbon, carbon dioxide, heat waste, nitrogen oxides, methane, particulates, total organic carbon, volatile organic compounds, and water. The details of LCI data for the landfill process are given in Table 1.

**Table 1:** Life cycle inventory for input and output flows of Scenario 1

| Input | Unit | Amount |
| --- | --- | --- |
| Kitchen waste | kg | 1000 |
| Transport, municipal waste | Kg x km | 1.9 x 104 |

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| Output | Unit | Amount |
|---|---|---|
| Ammonia | kg | 50.0002 |
| carbon | kg | 0.00057 |
| Carbon dioxide | kg | 24.105 |
| Heat waste | MJ | 0.075 |
| Nitrogen oxides | kg | 0.158 |
| methane | kg | 0.00013 |
| particulates | kg | 0.0225 |
| Total organic carbon | kg | 0.0247 |
| Volatile organic compound | kg | 0.00013 |
| water | kg | 22.875 |

LCI for kitchen waste disposal by biofertilizer production (Scenario 2):
1000 kg kitchen waste, 21.6 MJ of solar energy, 0.0233 KWh electricity were used as input (Table 2). 900 kg biofertilizer, 100 kg water vapour are used as output in the study. The details of LCI data for this process is given in Table 2.

**Life cycle impact assessment:**

Life cycle impact assessment (LCIA) was conducted using Open LCA software. The LCIA method used in this study is Recipe 2016 Midpoint (H) (Adhikari, 2024). The Recipe 2016 Midpoint uses 18 indicators (Adhikari, 2024) that impact the environment. They are agricultural land occupation, climate change, fossil depletion, freshwater ecotoxicity, water eutrophication, human toxicity, ionizing radiation, marine ecotoxicity, marine eutrophication, metal depletion, natural land transformation, ozone depletion, particulate matter formation, photochemical oxidant formation, terrestrial acidification, terrestrial ecotoxicity, urban land occupation, water depletion (Huijbregts, 2017).

**Table 2:** Life cycle inventory of input and output flows for Scenario 2.

| Input | Unit | Amount |
|---|---|---|
| Kitchen waste | kg | 1000 |
| Solar energy | MJ | 21.6 |
| Electricity | KWh | 0.023 |

| Output | Unit | Amount |
|---|---|---|
| Biofertilizer | kg | 900 |
| Carbon dioxide | kg | 18.98 |
| Heat Waste | MJ | 0.059 |
| Methane | kg | 0.011 |
| Nitrogen oxides | kg | 0.065 |
| Particulates | kg | 0.0006 |
| Total organic carbon | kg | 0.018 |
| Water | kg | 100 |

## 3. RESULTS AND DISCUSSION:

The plant setups were kept in sunlight and watered daily. Table 3 shows images of the plant growth every two days for two weeks for moong seeds. Table 4 shows images of the plant growth every two days for two weeks for Chana seeds.

**Table 3:** Stages of moong growing, starting from 0 day of fertilizer (2%) addition to 14 consecutive days. (a) compost (b) biofertilizer (c) control

| Day | Compost | Bio-fertilizer | Control (No fertilizer) |
|---|---|---|---|
| 0 |  |  |  |
| 2 |  |  |  |

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| | | | |
|---|---|---|---|
| 14 | <br>15 cm height<br>(10 seeds germinated) | <br>17 cm height<br>(13 seeds germinated) | <br>9 cm height<br>(8 seeds germinated) |

From the above pictures, it was observed that the germination of moong seeds started from day 4 of the study in the compost and the bio-fertilizer setups. The control setup did not show any germination at this point of time. From day 6 onwards, the bio-fertilizer plant was distinctly taller as compared to the compost and the control. On day 14, we noted that for the compost, 10 out of 15 seeds germinated, for the bio-fertilizer 13 out of 15 seeds germinated, and for the control, only 8 out of 15 seeds germinated. This clearly shows that the bio-fertilizer is better in performance as compared to the local compost and plain soil sample.

**Table 4:** Stages of chana growing, starting from 0 day of fertilizer (2%) addition to 14 consecutive days. (a) compost (b) bio fertilizer

| Day | Compost | Bio-fertilizer |
|---|---|---|
| 0 |  |  |
| 4 |  |  |

| | | |
|---|---|---|
| 6 |  |  |
| 8 |  |  |
| 10 |  |  |
| 14 |  |  |

From the above pictures, it was observed that the germination of Chana seeds started from day 4 of the study in the compost and the bio-fertilizer setups. From day 6 onwards, the bio-fertilizer plant was considerably taller as compared to the compost. At day 14, we noted in the compost set up that 9 out of 15 seeds germinated, and for the bio-fertilizer, 14 out of 15 seeds germinated. This demonstrates the superior performance of bio-fertilizer as compared to the local compost in the Chana setup. Thus, we found that the bio-fertilizer showed better performance than the local compost for both the seeds. For 5% by weight of the bio-fertilizer, there was no major improvement in the plant growth after one week. Hence, we concluded that 2% by weight of the bio fertilizer was optimum for the plant growth.

The elemental analysis of N (nitrogen), K (potassium), P (phosphorus), and S (sulphur) was performed on the following samples.

1. The original soil sample without fertilizer
2. The bio fertilizer mixture
3. Soil + bio fertilizer: This mixture was properly mixed, soaked with water for 2 days, and then dried in oven to remove moisture
4. Soil + compost: This mixture was properly mixed, soaked with water for 2 days and then dried in oven to remove moisture
5. Soil + bio fertilizer from moong sprouts at the end of 2 weeks
6. Soil + compost from moong sprouts at the end of 2 weeks

**Table 5:** Elemental analysis of soil samples

| Sr No. | Sample | % wt Nitrogen | % wt Phosphorus | % wt Potassium |
|---|---|---|---|---|
| 1 | soil sample without fertilizer | 0.55 | 0.17 | 0.68 |
| 2 | bio fertilizer | 0.99 | 0.18 | 0.24 |
| 3 | Soil + bio fertilizer (at the start) | 0.03 | 0.14 | 0.21 |
| 4 | Soil + compost (at the start) | 0.029 | 0.16 | 0.29 |
| 5 | Soil + bio fertilizer (end of 2 weeks) | 0.019 | 0.14 | 0.10 |
| 6 | Soil + compost (end of 2 weeks) | 0.024 | 0.13 | 0.10 |

The soil sample used in the study demonstrated optimal levels of N, P, and K elements essential for plant growth. As indicated in Table 5 (sr no. 3, 4, 5 & 6), phosphorus is minimally consumed during plant growth. Potassium consumption reached nearly 50% over two weeks in the soil + bio fertilizer setup (sr no. 3 & 5). Similarly, in the soil + compost setup, potassium consumption was approximately 65% during the same period (sr no. 4 & 6). This suggests that while potassium is crucial for plant growth, its effect does not significantly differ between the soil + compost and soil + bio fertilizer setups beyond a certain point. Nitrogen consumption was about 37% over two weeks in the soil + bio fertilizer setup (as seen from sr no. 3 & 5), whereas it was around 17% in the soil + compost setup (as seen from sr no. 4 & 6). The elemental analysis indicates that both nitrogen and potassium play a significant role in enhancing plant growth. These results suggest that the bio fertilizer developed in this study outperforms the local compost, even without undergoing the traditional composting process.

**Environmental impacts of different scenarios of kitchen waste disposal:**

The environmental impacts of two scenarios (Scenario 1 & 2 described above) were studied using Recipe 2016 Midpoint (H) methodology in OpenLCA software. The 18 impacts were grouped into four categories: Emission to air, Water, Land, and Resources & Human health. Table 6 shows the comparison of the impacts of the two scenarios in each of the four categories.

**Table 6**: Environmental Impact Comparison of Scenario 1 & 2

| Category | Impact indicators | Unit | Scenario 1 | Scenario 2 |
|---|---|---|---|---|
| Emission to Air | particulate matter formation | Kg $PM_{10}$-Eq | 0.057 | 0.040 |
| | climate change | kg $CO_2$-Eq | 24.82069 | 19.51916 |
| | ozone depletion | kg CFC-11-Eq | $4.5 \times 10^{-6}$ | $3.18 \times 10^{-6}$ |
| | photochemical oxidant formation | kg NMVOC | 0.240438 | 0.080716 |
| Water | freshwater ecotoxicity | kg 1,4-DCB-Eq | 0.04406 | 0.024472 |
| | marine ecotoxicity | kg 1,4-DCB-Eq | 0.040641 | 0.042876 |
| | freshwater eutrophication | kg P-Eq | 0.000598 | 0.000232 |
| | marine eutrophication | kg P-Eq | 0.063548 | 0.02804 |
| | water depletion | $m^3$ | 0.01113 | 0.019408 |
| Land | terrestrial acidification | kg $SO_2$-Eq | 0.12147 | 0.144246 |
| | terrestrial ecotoxicity | kg 1,4-DCB-Eq | 0.001042 | 0.002491 |
| | agricultural land occupation | $m^2$*a | 0.084038 | 0.032757 |
| | urban land occupation | $m^2$*a | 0.144916 | 0.028168 |
| Resource & Human Health | fossil depletion | kg oil-Eq | 8.941492 | 6.229827 |
| | metal depletion | kg Fe-Eq | 0.272708 | 0.104772 |
| | ionising radiation | kg U235-Eq | 1.738661 | 1.244322 |
| | human toxicity | kg 1,4-DCB-Eq | 1.082878 | 1.634108 |

Table 6 reveals that scenario 2 results in lower air emissions across all four indicators compared to scenario 1. Examining the water emissions data, we deduce that scenario 2 is more favorable for water ecotoxicity and eutrophication in both freshwater and marine environments than scenario 1. However, scenario 2 exhibits slightly higher water depletion than scenario 1. From a land perspective, scenario 2 results in reduced terrestrial acidification, decreased land toxicity, and occupies less land, both agricultural and urban, compared to scenario 1. In terms of resource and human health indicators, scenario 2 shows lower fossil depletion, metal depletion, and ionizing radiation. Nevertheless, while the human toxicity impact is low for both scenarios, scenario 2 is marginally higher than scenario 1. Based on the results from Table 6, we can conclude that scenario 2 outperforms scenario 1 in 16 out of 18 impact indicators. This suggests that recycling dry kitchen waste to produce biofertilizer is more sustainable than disposing of it in a landfill.

## 4. CONCLUSION:

This present study demonstrated that biofertilizer derived from dry kitchen waste, such as onion and garlic peels, banana and orange peels, tea grounds, and eggshells, significantly influenced the growth of sprout plants. When added to the soil of potted plants, the biofertilizer neither emitted any odour nor attracted flies, a common issue in traditional composting processes. The unpleasant smell generated by adding wet kitchen waste to a compost pit often makes it an unpopular method of waste recycling. The LCA study further confirmed that recycling dry kitchen waste into biofertilizer is more environmentally sustainable than disposing of it in landfills. Thus, drying the ingredients and creating a biofertilizer that can be easily and quickly produced at the source presents an attractive solution for utilizing dry kitchen waste. Since the study focused on only a few types of kitchen waste, there remains a wide array of waste materials that could enhance the quality of fertilizer. The ability to adjust the component ratios according to plant needs offers the flexibility to make the biofertilizer suitable for a diverse range of plant species.

## 5. CONFLICT OF INTEREST:

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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