Biofertilizer from Kitchen Waste: Potential for Sustainable Agricultural and Waste Management

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Abstract

The study examines the recovery of NPK in kitchen waste, with a focus on the production of nitrate, phosphate, and potassium The kitchen waste samples, include yam peels, banana peels, plantain peels, potato peels, egg shells, and cooked rice (sink waste), were collected from different kitchens in the city of Port Harcourt, Nigeria. This exhaustive study, employed diverse methodologies such as microbiological analysis to determine the total heterotrophic bacteria count (THB), and the total heterotrophic fungal count (THF). Subsequent studies were aimed at optimizing the extraction process by taking pH, temperature, and reaction time into consideration. The total Nitrate, phosphate and potassium was evaluated. Bacterial isolates were identified based on notable biochemical parameters. The bacteria genera include Bacillus spp., Klebsiella spp., Enterobacter spp., Salmonella spp., Citrobacter spp., Proteus spp., and Escherichia coli. While fungal isolates were identified based on macroscopy and microscopy, the genera include Penicillium spp., Candida spp., Fusarium spp. Aspergillus niger, Aspergillus flavus, Rhizopus spp., Trichoderma spp., Trichophyton tonsurans, Crytococcus spp., and Rhodotorula spp. The pH changes from acidic 3 to alkaline 8. The Nitrate, phosphate and potassium recovered ranged from 11.758 mg/kg – 29.114 mg/kg, 1.746 mg/kg – 6.972 mg/kg, 13.235 mg/kg – 22.784 mg/kg respectively. The study evaluated the suitability of the recovered nutrients for agricultural uses and their purity. Additionally, this strategy supports sustainable waste management techniques and the circular economy by keeping organic waste out of landfills and turning it into useful resources.

Keywords: *NPK recovery, kitchen waste, nitrate, phosphate, potassium, agriculture, sustainability, waste management*

INTRODUCTION

Kitchen garbage is a significant part of household waste and both resource-rich and hazardous at the same time. Globally, about 1.3 billion tons of kitchen garbage are produced annually. Kitchen waste smells bad, decomposes quickly, and contains a lot of moisture. Inappropriate handling of this trash may result in environmental contamination. (Chen *et al*, 2023). Bio-waste, which is often referred to as biological waste or bio-hazardous waste, is a broad category of waste products that

come from living things (WHO. 2017). These materials have biological properties that may be harmful to the environment, other living things, and human health. To successfully reduce these dangers, bio-waste must be managed and disposed of. A circular economy can be supported by the use of bio-waste, or trash created from various bio-based sources, which makes up about 20% of the garbage produced in the European Union. Bio-waste has the potential to yield valuable chemical compounds (Macaskie *et al*., 2019). Consequently, bio-waste valorisations are regarded as a desirable and different solution to waste management regulations. The amount of organic waste produced by human and animal habitations is enormous, and the open decomposition of this waste has an adverse effect on the quality of the soil, air, and water. Due to the variety of dangerous bacteria, they contain, the majority of biosolid wastes are extremely contagious.

Risks to human health and the environment arise from their release into the environment without first being disinfected. The global trash sector has been expanding at a pace of 2.8% annually. Vermicomposting facilitates the transformation of organic wastes, such as household garbage, animal dung, and agricultural wastes, into extremely nutrient-rich fertilizers for plants and soil (Yvonne et al., 2019). The maintenance of soil health, management, and nutrition are some of the primary issues surrounding the environmental effects of agriculture. This is particularly crucial because, by 2050, it is expected that the world's population will have grown by roughly 35%, which will drive further growth in the agricultural industry (Keeler *et al*., 2016). Nitrogen is utilized by all plants as NH_4^+ and NO_3^-. It is the most essential component for healthy plant growth and development, which greatly raises and improves the yield and its quality by being essential to the physiological and biochemical processes of plants (Leghari *et al*., 2018). It has an impact on the ratio of lysine and threonine amino acids in cereals. Increased nitrogen content improves the strength and quality of the kernels, which benefits the milling characteristics. Protein content and pod development in oil seeds both dramatically rise with nitrogen feeding (Arshad *et al*., 2018). According to Carranca *et al*. (2017), nitrogen has a good impact on a number of qualitative characteristics in fruit crops, including composition, texture, flavour, size, shape, and colour. According to Tahir Sheikh *et al*. (2018), the majority of nitrogen and phosphorus derived from agriculture are found in the organic waste components of farms, homes, and the food sector. (Tahir Sheikh *et al.*, 2018; EPA, 2021).

This research project aims to investigate novel approaches for obtaining vital nutrients—nitrate, phosphorus, and potassium—from bio-waste materials such as egg shells, cooked rice, banana, plantain, and yam peels—a.k.a. kitchen waste. One of the study's goals was to ascertain how many nutrients kitchen garbage contains. (ii) To calculate the total counts of heterotrophic fungi and bacteria (THF and THB, respectively).

Materials And Methods

Materials: Sample Collection

The samples used include yam peels, banana peels, potato peels, plantain peels, egg shells, and cooked rice (sink waste), which were randomly collected from different kitchens. There

were two sets of treatment: Set up 1 (BPRE); Banana (60g), Potatoes (200g), Rice (200) g, Egg (100 g) giving a total of 560g. And set up 2 (REPY); Rice (200g) Egg (100g), Plantain (60g) Yam (200g), giving a total of 560g. All of these were sundried, after which they were grinded separately.

Microbial culture analysis

One gram (1g) of BPRE and one gram (1g) of REPY were measured out of 560g and added to 9 ml of normal saline in various test tubes to prepare a stock culture, 400 ml of water was added to each of the labeled samples in a bucket and stirred until well mixed. 1 ml of sample was collected from each stock culture and added to a normal saline of 9 ml, at titrate 4, 2 drops each were taken and introduced into the PDA and NA plates, respectively, and labeled 10^4 for each set up. At titrate 6, 2 drops each were taken and introduced into the PDA and NA plates, respectively, and labeled 10^6 for each set up. (Lin *et al*., 2020)

Identification of Isolate

The isolates that were identified were obtained from the bijou bottles, inoculated on a nutrient agar plate by streaking, and kept at 37 °C for 24 hours. After incubation, the new isolates were subjected to Gram staining and other biochemical analyses such as Sugar Fermentation test, Motility test, Citrate test, Indole Test, Oxidase test as described by USFDA (2017), Methyl Red and Voges Proskauer (MR-VP) test. The bacterial isolates were identified using Bergey's Manual of Determinative Bacteriology (Murhammer,2018).

Lacto-Phenol Test (Wet Mount)

The test aimed to identify fungal isolates based on their structure. Two drops of phenol dye were added to a clean slide, and a sterilized wire loop was used to pick up fungal growth, creating a smear on the slide. The smear was covered with a slip and examined under a microscope using a 40x lens.

Physicochemical Parameters

Determination of pH

This was carried out using a pH meter; the electrode was calibrated using a buffer of pH 7.0; it was rinsed with distilled water and dipped into the sample for both setups; the pH was displayed on the screen; and it was allowed to stabilize for five minutes before taking the reading. ((Patel and Vashi, 2015).

NPK (nitrogen, phosphorus, and potassium) analysis

The measurement of NPK (nitrogen, phosphorus, and potassium) in the fertilizer samples derived from kitchen waste was conducted using chemical analysis techniques. 10 grams of each sample were collected. A digestion block was used to aid in the breakdown of the samples' organic and inorganic components, and a vacuum pump filtration system was used to filter the material.

Using the Total Kjeldahl Nitrogen (TKN) method, as developed by Johan Kjeldahl, the nitrogen concentration was ascertained. A strong sulfuric acid solution (H_2SO_4) was used to breakdown the nitrogen-containing molecule while copper sulfate served as a catalyst. Nitrogen underwent conversion to ammonia (NH_3), followed by titration, distillation, and calculation. The molybdenum blue method (colorimetric method) was used to analyze phosphorus. The molybdenum and phosphorus interacted to create a blue complex, whose intensity was measured. For potassium analysis, flame photometry instrumentation was used to measure the intensity of light emitted by atoms in a flame. The sample solution containing potassium ions was nebulized into a flame at a high temperature, causing the atoms to emit light. The emitted light was then passed through a monochromator to isolate the specific wavelength associated with potassium. A detector was used to gauge the light's intensity. Calibration standards with known concentrations for each nutrient were used to create a calibration curve to ensure accurate measurements. The analysis' accuracy and precision were then validated using a quality control measure. The data was processed to assess the NPK content of the kitchen waste-derived fertilizer sample.

Evaluation of Compost Set-ups

Beans seeds were planted on both compost set-ups (BPRE and REPY) to access the rate at which each will support plant growth. The number of stems, numbers of leaves, length of stem, length of leaves and the color of leaves were recorded for two (2) weeks.

Results and Discussion

Using kitchen garbage, such as yam, banana, potato, plantain, eggshells, and cooked rice, a dark brownish to black compost with an earthy fragrance was produced. It took 56 days to make the high-quality compost.

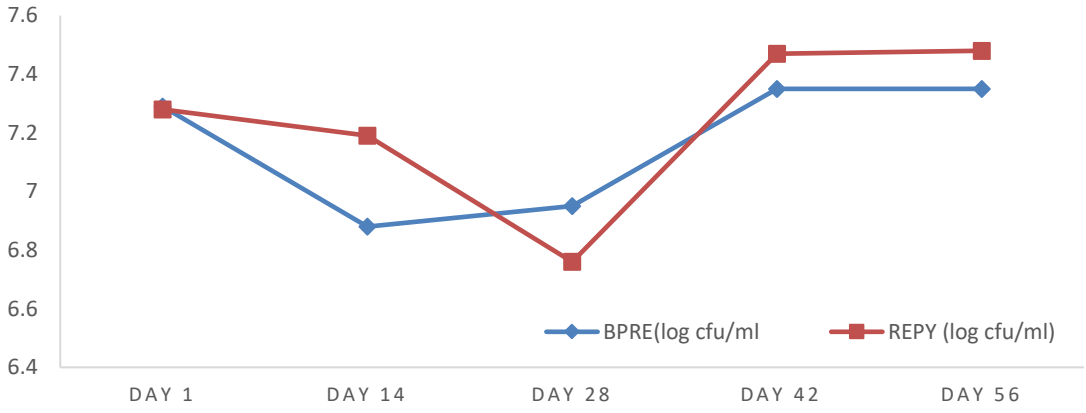

FIGURE 1: TOTAL HETEROTROPHIC BACTERIAL COUNT

Isolate ID	Catalase	Lactose	Indole	MR	VP	Citrate	TSIA butt	TSIA slant	H_2S	Gas	Motility	Gram stain	Probable Genera
IC1	+	-	+	+	-	+	A	A	+	-	-	- rod	*Escherichia coli*
IC2	+	+	+	-	+	-	A	A	+	-	-	+ rod	*Enterobacter* spp.
IC2a	+	-	+	-	-	+	A	B	+	-	+	- rod	*Proteus spp.*
IC3	+	-	-	-	-	+	A	B	+	-	+	- rod	*Salmonella* spp.
IC4a	+	-	+	+	-	+	A	B	+	-	+	- rod	*Proteus spp.*
IC4b	+	+	+	-	-	+	A	B	+	-	+	- rod	*Klebshiella pneumoniae*
IC5	+	-	+	-	-	+	A	B	+	-	+	+ cocci	*Enterococcus* spp.
IC6	+	-	+	-	-	+	A	B	-	-	+	- rod	*Proteus* spp.
IC7	+	-	+	+	-	-	B	B	-	-	+	- rod	*Escherichia coli*
IC8	+	-	-	+	-	+	A	B	+	+	+	- rod	*Citrobacter* spp.
IC9	+	-	-	-	-	-	A	A	-	-	-	+ rod	*Bacillus* spp.
IC10	+	-	-	-	-	-	A	B	-	-	-	+ rod	*Bacillus* spp.
IC11	+	+	-	-	-	+	A	A	+	-	+	- cocci	*Enterobacter* spp.
IC12	+	+	+	+	-	+	A	B	+	-	+	- rod	*Escherichia coli*
IC13	+	+	-	+	-	+	A	B	+	-	+	- rod	*Escherichia coli*
IC14	+	+	+	+	-	+	A	B	+	-	+	- rod	*Escherichia coli*
IC15	+	+	-	+	-	+	A	B	+	-	+	- rod	*Escherichia coli*
IC16	+	-	-	+	-	+	A	B	+	-	-	+ cocci	*Staphylococcus* spp.
IC17	+	+	+	-	+	+	A	B	-	-	+	- rod	*Escherichia coli*
IC18	+	-	+	+	-	+	A	B	-	-	+	- rod	*Enterobacter aerogenes*
IC19	+	-	+	-	+	-	A	B	-	-	+	- rod	*Klebshiella pneumonia*
IC20	+	-	+	-	+	-	A	B	-	-	+	+ rod	*Escherichia coli*

Table 1: Biochemical characteristics of bacteria isolates

KEY A= Acid, B=Base

Table 2: Cultural Morphology of Fungi Isolates

Sample	Isolate code	Surface Colour	Reverse Colour	Mycellia Growth	Shape	Size (mm)	Fungi Present
BPRE	ICF1	BW	Creamy	Present	Circular	80	*Rhizopus* spp.
REPY	ICF2	BC	Creamy	Present	Circular	40	*Aspergillus niger*
	ICF3	GW	White	Present	Circular	60	*Pencillium* spp.
	ICF4	GY	Yellow	Dense Mycellia	Irregular	45	*Aspergillus* spp.
	ICF5	WW	Creamy	Present	Irregular	23	*Fusarium* spp.
			Day 14				
BPRE	ICF_6	WW	Cream	None	Irregular	64	Mold
	ICF_7	Green	Green	Present	Irregular	72	*Trichoderma*
REPY	ICF_8	White	Cream	None	Circular	19	Yeast
			Day 28				
REPY	ICF10	WWS	Cream	Present	Circular	50	*Aspergillus niger*
REPY	ICF9	WW	Cream	None	Circular	45	Yeast
			DAY 42				
REPY	ICF11	RS	Red	None	Circular	10	*Trichophyton tonsurans* Yeast
	ICF12	WY	Yellow	Present	Circular	10	*Fusarium*
BPRE	ICF13	Lemon green	Cream	Presence of spores	Irregular	15	*Aspergillus flavus*
			DAY 56				
BPRE	ICF14	Yellow	Yellow	None	Circular	10	*Crytococcus*
	ICF15	Pink	Pink	None	Circular	10	*Rhodotorula*
REPY	ICF16	WW	Brown	Present	Circular	85	*Fusarium*

KEY:BW: Black with white margin, BC: Black with creamy margin, GW: Green with white margin, GY: Green with yellow margin, WW: White with white margin, WWS: White with

white segmented margin, RS: Red with smooth and shiny margin, WY: White with yellow margin

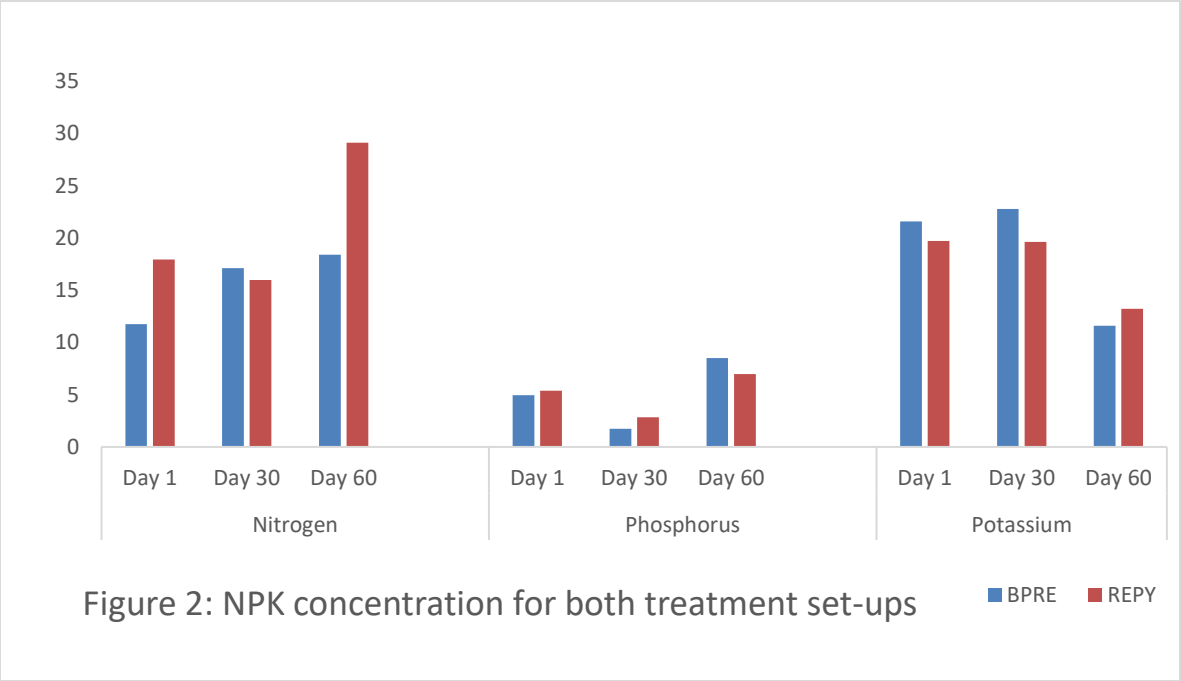

Figure 2: NPK concentration for both treatment set-ups

Table 3: pH of both set ups at different days

DAYS	pH Value	
	BPRE	**REPY**
DAY 1	3	4
DAY 14	4	5
DAY 28	5	6
DAY 42	6	7
DAY 56	7	8

Table 4: Result from planting bean seed using the compost set ups

Planting Date	Sample	Stem number	Leaf number	Leaf colour	Leaf length (cm)	Stem length (cm)
Initial Day	BPRE	-	-	-	-	-
	REPY	-	-	-	-	-
DAY 5	BPRE	2	-	-	-	4.2
	REPY	3	2	Green	1.8	7.5
DAY 7	BPRE	2	3	Green	2.0	7.9
	REPY	3	6	Green	2.7	14.5
DAY 10	BPRE	3	4	Green	3.9	8.5
	REPY	3	9	Green	3.4	15.7
DAY 12	BPRE	3	5	Green	4.3	11.7
	REPY	3	9	Green	4.1	16.3

For BPRE, the total heterotrophic bacterial (THB) count varied between 6.88 and 7.35 log cfu/ml, whereas for REPY, the range was 6.76 to 7.48 log cfu/ml. *Escherichia coli* (36.4%), *Enterobacter* spp. (13.6%), *Proteus* spp. (13.6%), *Samonella* spp. (4.5%), *Klebshiella pneumonia* (9.1%), *Enterococcus* spp. (4.5%), *Citrobacter* spp. (4.5%), *Bacillus* spp. (9.1%), and *Staphylococcus* spp. (4.5%) were the bacterial genera that were isolated and their percentage frequency of occurrence. Table 2 lists the fungal genera that were isolated: *Rhizopus* species, *Aspergillus niger*, *Penicillium* species, *Fusarium* species, *Mold*, *Trichoderma*, *Yeast*, *Trichophyton tonsurans*, *Aspergillus flavus*, *Rhodotorula*, and *Crytococcus*. Other researchers have also isolated similar organisms (Williams and Davis, 2020; Yvonne *et al*., 2019).

In addition to managing the majority of the organic material in the waste stream, composting offers a way to recycle solid wastes and can be used to handle sewage sludge, paper products, farm wastes, restaurant waste, kitchen waste, leaves, and domestic wastes (Viktoria *et al*., 2021). From improving soil fertility to providing a dependable method of waste transformation, organic waste materials, primarily of plant and animal origin, are possible sources of organic matter and plant nutrients (Ksawery *et al.*, 2023; Kamur *et al*.,2021). Every time the composting was turned to aerate it, the microbial load rose. This finding suggests that turning the composting pile increases the oxygen content, which promotes the growth of microorganisms. This result is consistent with the findings of Williams and Davis (2020) and Viktoria *et al*. (2021), who found that the compost's microbial population increased to a maximum extent as a result of favourable environmental

circumstances. The alterations seen may be attributed to the microbial synthesis and use of diverse nutrients, as well as the advantageous environmental circumstances found in the composts (Viktoria *et al*., 2021; Nele, *et al*., 2018: Olivera *et al*., 2018). It is possible to propose that the groups of microorganisms isolated during the first and subsequent weeks of composting are accompanying microbes that can break down plant waste.

Research has shown that microbial activity increases the probability of reaching a good pH range of 5.5-7.0, and that pH values between 6.5 and 8.0 are optimal for the composting process in our research the pH changes from acidic (3) to alkaline (8) as shown in table 3 which is within the optimal pH value (Viktoria et al., 2021; Kumar, et al., 2021).

Both compost configurations were tested to see if they would actually encourage plant development, as seen in Table 4. After five days of planting bean seed using both setups (BPRE and REPY), the plant sprouted, and the growth parameters were tracked over the following few days. Since the plants in both settings grew together, it can be concluded that both set-up support plant growth. However, even after an identical number of days, the REPY plant grew quicker than the BRPE plant, having 4.65 % increase in leaf length and 28.2 % increase in stem length than BPRE; it can be concluded that REPY is more enriched than BPRE. (Ksawery et al., 2023; Nele, *et al*., 2018: Olivera *et al*., 2018).

The early stage saw the largest levels of bacteria and fungi, which subsequently reduced (Viktoria *et al*., 2021; Olivera *et al*., 2018). Numerous bacterial genera, such as Salmonella, Klebsiella, Citrobacter, Bacillus, Escherichia coli, Enterobacter, Proteus, and Staphylococcus, were isolated. Over time, maturation was indicated by a decrease in pathogenic microorganisms and an increase in Bacillus species (Ksawery et al., 2023; Kumar *et a*l., 2021). The research shows the occurrence of yeast as the compost matures.

Day 56 saw a plateau in pH, phosphate, and nitrogen variations, indicating stability (Ksawery *et al*., 2023). REPY have higher concentration of nitrogen and potassium than BPRE while BPRE have higher concentration of phosphate than REPY. The findings show that REPY has less phytotoxicity than BPRE compost, effective decomposition from early to mature stages, and good maturity and stability by day 56 (Viktoria *et al*., 2021; Ksawery *et al*., 2023; EPA, 2021). The survival of living things could be seriously threatened by environmental contamination. The improper use of chemical pesticides and fertilizers might worsen the state of the ecosystem. The choice of the best raw material is crucial to a successful composting process, and this substrate is easily obtainable and reasonably priced (Nele, *et al*., 2018: EPA, 2021).

CONCLUSION

The current study has shown that kitchen waste would provide an excellent substrate for the economically significant process of producing biofertilizer when set up correctly, as we did in both ups (BPRE and REPY). It has been demonstrated that microorganisms accelerate degradation; using them in composting offers an alternate approach to waste management as chemical and thermal approaches are less efficient in terms of energy use and composting. Microorganisms that

compost increase the amount of nutrients in the compost and improve its breakdown. The decrease in pH that occurred during the composting of the solid waste was caused by the actions of the microorganisms that made up the effective microorganisms.

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