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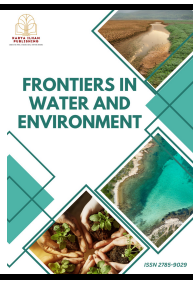

Utilizing Orange Waste, Chicken Droppings, and Rice Husk for Bio-Fertilizer Production via Anaerobic Digestion

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ABSTRACT

Frequent overuse of chemical fertilizers has caused significant ecological damage and nutrient loss in the soil. This highlights the need for an alternative source of plant nutrients to promote effective growth and increased yield. This article studied the potential of using orange waste in a mixture of chicken droppings and rice husks to produce a bio-fertilizer. Firstly, the levels of Nitrogen (N), Phosphorus (P) and Potassium (K) in the waste were determined, after which the mixture was fermented at 28–34°C for 45 days. Then, the growth and absorption capacity of Zea mays (maize) grown in soil mixed with different concentrations of the bio-fertilizer was investigated. The higher moisture, ash, crude protein and lipid content of the chicken droppings, as well as the carbohydrate content of the orange waste, indicated a higher amount of N, P and K (4.34±0.53, 782±11.0 and 1802±35.0), respectively. Furthermore, the bio-fertilizer contained *Pseudomonas, Clostridium, Proteus, Salmonella, Klebsiella, Bacillus, E. coli, Rhizopus, Aspergillus* and yeast cells. Soil fortified with 5 g of biofertilizer achieved optimal plant growth, leaf production, dry matter assimilation, and adsorption capacity. This promotes plant growth and development and improves nutrient assimilation efficiency.

1. Introduction

There is a global crusade for increased per capita agricultural production to alleviate food security challenges due to the expanding world population [1]. Thus, African farmers who are the major factor in food productivity have been encouraged to increase production [2, 3]. However, the poor soil, harsh climatic conditions, including high temperature and drought, the poor economic situation, lack of technological development and inefficient farming practices have significantly

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affected crop productivity in Africa as reported by Tully, Sullivan [4]. Presently, organic and chemical fertilizers are the major nutrient management methods for increasing crop productivity (Rahman and Zhang, 2018), although, challenges bordering on availability, cost, and management have limited the use of organic fertilizers amongst African farmers [2]. Whereas, chemical fertilizers are costly, unsustainable and contribute to environmental pollution and soil structure degradation.

The ecological damage caused by the overuse of chemical fertilizers have become increasingly uncontrollable, irreversible and causing significant nutrient loss to soils [5, 6]. Furthermore, currently, the short shelf-life of the microbial inoculants is affecting the effectiveness of the biofertilizers due to lack of producing the required yield in plants. This gap hinders enrichment of the biofertilizer with adequate plant growth supporting nutrients and limits commercialization of biofertilizer for large scale agricultural production. Therefore, the search for an economical, eco-friendly and sustainable solution for improving soil fertility that would lead to plant growth and yield is a golden ticket. This made the exploration of biomaterials toward producing what called bio-fertilizer. Bio-fertilizers are biologically active formulations comprising beneficial living microbes that can improve plants' live and yield, by enhancing the supply of plant growth-promoting nutrients [7]. Such fertilizer is harmless, environmentally friendly preventing damages to natural resources, clean nature from precipitated chemicals and improves the technique of the conversion of waste to wealth [8]. Furthermore, it is an essential constituent of sustainable food production and worth in supplying other benefits such as abiotic stress tolerance, phyto-stimulation and biocontrol [9, 10].

Starring to that is the interaction between the source materials (biological waste) and microorganisms (mostly anaerobic) which improve the aggregate and the soil structure becomes loose. Anaerobic chamber for the decomposition and digestion of the waste is conceive as waste-to-energy technology [11]. The results of decomposition by soil microorganisms can function as adhesives between soil particles to increase the amount of soil pores and eventually become a suitable medium for plant growth. Moreover, researches on bio-fertilizer in Nigeria have focused on the utilization of animal dung, human excreta, chicken droppings, and kitchen wastes as substrates while the use of plant products is limited [12, 13]. However, Nigeria is considered as the major waste producer in Africa with numerous types of waste generated (both organic and inorganic) [10]. Sweet orange (*C. sinensis*) peels and rotten ones are among the waste generated in Nigeria [14]. Likewise, rice husk and chicken dropping were reported as good substrate for quality bio-fertilizer [15]. Hence, to overcome this, the utilization of available waste such as orange waste is significant and serve as an excellent alternate to chemical fertilizers [16]. The study aimed to determine the potential of the orange waste (higher amount) and, chicken dropping and rice husk (lesser amount) to produce bio-fertilizer that has the capacity to conserve soil properties. As well, sustainable for farming system that produces healthy crops without damaging the environment.

2. Methodology

2.1 Collection of Raw Materials and Pre-treatment

Orange waste, rice husk and Chicken dropping waste were collected in a waterproof sack from different parts of Gombe metropolis, Gombe State, Nigeria. Orange waste was air-dried under shade for 2-weeks at an average mesophilic temperature of 28.5℃, while Chicken droppings was sun-dried for 3-days at an average mesophilic temperature of 28.5℃. The raw materials were pre-treated by removing the unwanted materials and later grinded separately using standard BLG-401-18N blender in Biology laboratory of Gombe State University (GSU), Nigeria [17].

2.2 Proximate Analysis of the Raw Materials

2.2.1 Moisture Content

The moisture content of the individual raw material was determine as described by [18]. Two grams of the individual substrate was used and the moisture content percent was calculated using the expression;

$$\% \text{ moisture } = \frac{\text{Loss of weight on drying(g)} \times 100}{\text{Initial sample weight}}$$

2.2.2 Ash Content

The method for ash content determination proposed by [18] was employed and the percentage was calculated using the formulae;

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of dry sample}} \times 100$$

2.2.3 Crude Lipid Content

The lipid content of the raw materials was determined as described by [18]. Soxhlet extractor was used and the process was observed for 5 hours to and the crude lipid content was calculated using the formulae;

$$\% \text{ lipid } = \frac{\text{Weight of lipid extracted } \times 100}{\text{Weight of dry sample}}$$

2.2.4 Crude Fibre

Crude fibre was determined by the method of [18]. Two grams of each waste sample was place mixed with 100 ml of 0.25M H_2SO_4, boiled for 30 minutes and the insoluble matter was washed until it was acid free (C1). It was then transferred into a flask containing 100 ml of 0.25M NaOH solution, boiled as before and filtered under suction and the insoluble residue was washed with hot water until it is base free (C2). It was then turned to powder in a furnace at 100^{o}C oven, allowed to cooled and re-weighed (C3). The crude fibre content was calculated using the formulae;

$$\% \text{ crude fiber } = \frac{\text{C2} - \text{C3} \times 100}{\text{W}}$$

2.2.5 Crude Protein Content

The Kjeldahl method of [18] was employed for the crude protein determination. Similarly, 2g of each raw material was transferred into 100 ml Kjeldahl flask and few anti-bumping granules were added. One gram of the mixed catalyst ($CuSO_4$ and K_2SO_4 (8:1 ratio)) and 15mL of concentrated sulphuric acid were added. The flask was heated until a clear solution was obtained, then cooled. The sample was transferred to a 100 ml volumetric flask and made up to the mark with distilled water. About 10 ml of the digest was pipetted into Markham semi-micro nitrogen steel tube and 10 mL of 40% NaOH solution was added.

The sample was then steam distilled liberating ammonia into a 100mL conical flask containing 10 mL of 4% Boric acid and a drop of methyl blue indicator was added until the colour changed from pink to green. The content of the conical flask was then titrated with 0.1M HCl. The end-point was

indicated by a colour change from green to pink and the volume (v) of the acid for each was recorded. Percentage nitrogen per sample was calculated using the formulae below:

$$\% \text{ Nitrogen} = \frac{\text{M} \times \text{v} \times 14 \times 100 \times 100}{\text{Weight of sample} \times 1000 \times 10}$$

Where: M = Molarity of HCl
14 = Atomic weight of nitrogen
100 = Total volume of digest
100 = % conversion
10 = Volume of the digest taken
1,000 = Conversion to litre.
Whereas, the crude protein was calculated as; % Protein = 6.25 x % nitrogen.

2.2.6 Carbohydrate Content

Carbohydrate content [18] was determined using the expression as follows;
% carbohydrate = 100 - (% ash + % crude fibre + %crude fat + % moisture + % crude protein).

2.3 Microbial Analysis of Raw Materials

Standard methods for bacterial and fungal species isolation were carried out to determine the microbial content of the mixed substrate before and after the digestion (biofertilizer production). For substrate, microscopy and biochemical tests were carried out to identify the microbial load of the homogenized mixture. The biochemical test carried out are; glucose, lactose, motility, sucrose, citrate, urease, indole, H2S (Hydrogen Sulphide) and Voges-proskeur as descried by Hassan and Abdulsalam [17].

2.4 N, P, K Analysis of Raw Materials and Dilution

Firstly, the elemental compositions including N, P and K of the individual waste (orange waste, chicken dropping and rice husk) was determined using DR/890 colorimeter and atomic absorption spectroscopy (AAS). One thousand, four hundred grams (1.4 kg) of the respective raw materials was mixed with water at 1:1 ratio. The substrate was homogenized for easy loading and digestion in an anaerobic digester (desiccator). The substrate occupied 79 % of the desiccator volume leaving a clear space of 21 % for biogas production as described by LUMULA [7].

2.5 Anaerobic Digestion and N, P, K Analysis of Bio-fertilizer
2.5.1 Anaerobic Digester Feeding

Subsequent to the dilution and loading of the waste raw materials into the bio-digester, it was allowed to ferment for 45 days at mesophilic temperature (28 ^{0}C - 34 ^{0}C).

Substrate input is given as:

Sd = Biomass (B) + Water (W) [=]m^3/ day

The total volume of the desiccator (V_T) is greater than the operating volume just to give room for the expansion in volume of the slurry during fermentation [17, 19].

The total volume is given as:

$V_T = \frac{V_o}{0.8}$ [=] m³

Bio-fertilizer yield is given as:

$$\text{Biofertilizer yield} = \frac{\text{mass of the digestates biofertilizer produced}}{\text{mass input of the substrate}} \times 100$$

2.5.2 N, P, K Analysis of the Produced Bio-fertilizer

Prior to the N, P, K analyses, pH and temperature of the produce were determined using metres. The total N, P, K of the bio-fertilizer was determined by wet digestion of the manure, which involves destruction of organic matter using both heat and acid. Hydrogen peroxide was used to enhance reaction speed and to complete the digestion. After digestion was completed, the sample was allowed to cool. The fertilizer was diluted to meet analytical requirement and analyzed using AAS [20, 21].

2.6 Determination of Microbial Content of the Bio-fertilizer

The microbial population in the desiccators was cultured and carefully isolated by standard plate count techniques using 0.5 mL aliquots of appropriate dilution. A drop of 10^{-10} serial diluted aliquot was used on the Nutrient agar for bacteria and the plates were incubated at 37℃ for 48 hours. Identification of individual colony was carried out by gram staining for morphology and biochemical tests (as described above). Whereas for fungal isolates, the microscopic and macroscopic features of the hyphal mass, morphology of cells and spores, nature of fruiting bodies was considered for the identification [17].

2.7 Plant Material, Bio-fertilizer Application and Growth Parameters Analyses
2.7.1 Digestion of Planting Soil

Soil sample was collected from Botanical Garden of GSU and digested with 25 mL of a mixture of Hydrochloric acid (HCl) and Trioxonitrate acid (HNO_3) (3:1). The mixture was continuously added into the digestion flask on a hot plate for 3 hours under the high temperature until the color of the sample changed into pale yellow. The sample was allowed to cool and filtered which made up to 100 mL mark with deionized water [22]. Blanks were prepared to check for background contamination by the reagents used.

2.7.2 Bio-fertilizer Application and Determination of Growth Parameters

The seeds of maize plant were bought from Gombe main market and sown (2-seeds per pot) into the soil at the depth of 3 cm. Prepared soil was used and mixed with 3g, 5g and 10g of the produced biofertilizer and blank (+ chemical fertilizer and - without fertilizer) [23]. The growing seedlings were irrigated after 48 hours in the nursery. After four weeks, few maize seedlings from the respective treatment and blank were uprooted, washed and air-dried for fertilizer uptake analysis. They were weighed and oven-dried at 60 °C for 48 hours and later separated into root, shoot and leaves [24]. The individual organs were turned into powder using pestle and mortar, and sieve through 0.18mm. One gram of the fraction was weighted into the digestion flask and added 3mL of concentrated HCl + HNO_3, then filled-up to 100 mL mark with distilled water. Blank was also prepared for the AAS analysis using the standard method described by de Matos Nascimento, Maciel [25].

Whereas, the remaining nursery plants were allowed to grow to certain stage and their growth parameters were analysed. The parameters measured, were growth rate, leaf area ratio, leaf area index, total dry matter production, and net assimilation rate from the growing plants [7].

2.8 Statistical Analysis

All experimental data generated were analyzed and interpreted using descriptive statistics interpreted as means and standard error of mean (SEM). The mean values for the maize growth parameters were subjected to multiple comparisons of Two-way Analysis of Variance at 95 % (p<0.05) confidence level using GraphPad Prism Software (GraphPad Inc., San Diego, CA, USA) [7, 17, 23].

3. Results

3.1 Nutrient Content (Proximate) of Individual Feedstock

The proximate compositions of orange waste, chicken dropping, and rice husk before dilution is presented in Table 1. Chicken dropping was discovered to have the highest moisture (3.27%), ash (12.46%) and lipid content (5.28%). Rice husk is the richest in crude fiber (28.26%), followed by orange waste (11.64%), while Chicken dropping has negligible amount (0.13%). Crude protein (24.63%) was more in chicken dropping, suggesting it as an excellent protein source. Orange waste gave the optimal carbohydrate content (69.09%) that is slightly higher than that of rice husk (65.97%).

Table 1
Nutrient composition of orange waste, chicken dropping and rice husk prior to dilution.

Samples	Proximate Composition (%)					
	Moisture	**Ash**	**Lipid**	**Crude fibre**	**Crude protein**	**CHO**
Orange Waste	1.5 ± 0.13 [a]	5.83 ± 0.10 [a, b]	3.42 ± 0.06 [a]	11.64 ± 0.25 [a]	8.50 ± 1.34 [a]	69.09 ± 2.86 [a]
Chicken Dropping	3.27 ± 0.15 [a]	12.46 ± 0. 12 [c]	5.28 ± 0.05 [a]	0.13 ± 0. 01 [b]	24.63 ± 2.14 [b]	57.5 ± 1.34 [b]
Rice Husk	1.98 ± 0.11 [a]	2.59 ± 0.08 [a]	0.62 ± 0.01 [a, b]	28.26 ± 0.23 [c]	0.58 ± 0.03 [c]	65.97 ± 1.76 [a, c]

The values are expressed as mean ± standard error of mean (SEM) of replicate (n = 3). Values with ‘a’ superscript in the same column do not significantly differ (p < 0.05). Whereas, those with ‘b’ and ‘c’ superscripts in the same column differ significantly from other samples (p < 0.05).

3.2N, P, K Composition of Individual Feedstock

The elemental composition of the three raw materials used is presented in Table 2, with focus on percentage of N, and P, K content in mg/100g. The relative percentage of the N composition was low compared to K and P that has the higher values. Phosphorus has moderate concentration value in all the three-waste used. This provides an insight on the potential of the diverse waste in producing bio-fertilizer.

Table 2
Elemental composition of samples before digestion.

Raw material	Nitrogen (%)	Phosphorus (mg/100g)	Potassium (mg/100g)
Orange waste	1.36 ± 0.15	43.62 ± 1.12	632 ± 5.0
Chicken dropping	3.94 ± 0.17	1365.47 ± 21.0*	1135 ± 27.0
Rice husk	16.74 ± 2.23*	16.74 ± 1.53	41.85 ± 1.26*

Values are expressed as mean ± standard error of mean (SEM) of replicate (n = 3). Values with asterisk '*' in the same column differ significantly from others ($p < 0.05$).

3.3 Microbial Composition of the Feedstocks and Bio-fertilizer

Microbial counts of the isolates from the respective raw materials and produced in a desiccator is presented is Table 3. Colony-forming units per gram (CFU/g) at different dilutions (10^{-1}, 10^{-5} and 10^{-10}) resulted in identifying some bacteria belonging to genus *Salmonella* and *Klebsiella*, alongside other bacteria including *Bacillus species, Pseudomonas species*, *Proteus species* and *E. coli*. Fungal species isolated include *Rhizopus* and *Yeast* cells, suggesting a diverse microbial population in the substrates before the dilution. Subsequent to the fermentation for 45 days, presence of *Salmonella species* and *Klebsiella species* persisted, and *Rhizopus* remains prevalent. Additional bacterial genus identified was *Clostridium*. The fungal species list expanded to include *Aspergillus* and yeast cells (Table 3).

Table 3
Microbial counts of bio-digester substrates before and after digestion.

Feedstuff condition	Microbial genus	
	Bacteria	**Fungi**
Before dilution	*E. Coli, Bacillus, Pseudomonas, Proteus, Salmonella* and *klebsiella.*	*Rhizopus* and *Yeast* cells
After dilution	*E. Coli, Pseudomonas, Clostridium, Proteus, Salmonella, Klebsiella.*	*Rhizopus, Aspergillus* and *Yeast cells*

Table 4, indicate their (microbial isolates) ability to metabolize different substrates and produce specific enzymes or compounds. The biochemical tests resulted in obtaining the potential of the bio-fertilizer to influence soil microbial communities and contribute to soil fertility.

Table 4
Biochemical test of isolates from bio-fertilizer.

Isolates	Ur	Vp	Lac	Glu	Suc	Ind	Cit	H_2S	Mot	Species of organism
A1	-	-	+	+	-	+	-	-	-	*E. Coli*
A2	-	-	-	+	-	-	+	+	+	*Salmonella spp*
A3	+	+	+	+	+	-	+	-	-	*Klebsiella spp*
A4	+	-	+	+	+	-	+	+	-	*Clostridia Spp*
A5	d	-	-	d	-	-	+	-	+	*Pseudomonas spp*
A6	+	-	-	+	+	+	d	-	+	*Proteus spp*
A7	-	-	+	+	+	-	-	-	-	*Yeast cells*
A8	+	-	+	+	+	-	-	-	-	*Rhizopus spp*
A9	+	-	+	+	+	+	+	+	-	*Aspergillus spp*

Key: Ur (Urease), Vp (Voges-Proskauer), Lac (Lactose), Glu (Glucose), Suc (Sucrose), Ind (Indole), Cit (Citrate), H2S (Hydrogen Sulphide), and Mot (Motility).

3.4 The Quality of Bio-fertilizer Based on N, P, K Concentration

Table 5 presents the elemental composition of the compost mixture and the planting soil used. This analysis focused also on the percentage of N and, P, K contents (mg/100g). The high nutrient concentrations obtained in the compost mixture after digestion suggest its potential as a potent soil amendment, providing a rich source of N, P, K. However, the relatively low nutrient levels in the soil suggest that while some nutrient transfer occurs, the efficiency of nutrient absorption might be limited or influence by other soil factors.

Table 5
Elemental composition of bio-fertilizer and soil.

Sample	Nitrogen (%)	Phosphorus (mg/100g)	Potassium (mg/100g)
Biofertilizer	4.34 ± 0.53 [a]	782 ± 11.0 [a]	1802 ± 35.0 [a]
Soil	0.18 ± 0.03 [b]	32.95 ± 1.08 [b]	117.24 ± 4.65 [b]

Values are expressed as mean ± standard error of mean (SEM) of replicate (n = 3). Values with 'a' superscript in the same column do not differ significantly with the soil ($p < 0.05$), while values with 'b' superscript in the same column differ significantly with the soil ($p < 0.05$).

3.5 Agronomic Response of Maize Grown in Different Bio-fertilizer Application

Table 6 presents the growth parameters of the maize grown under different application of bio-fertilizer, and control (+ and -). The parameters measured include Growth Rate (GGR), Total Dry Matter Production (TDMP), Leaf Area Ratio (LAR), Leaf Area Index (LAI), and Net Assimilation Rate (NAR). These parameters are critical for assessing the effectiveness of the fertilizers in promoting plant growth and development.

Table 6
Growth parameters of the maize grown under different application of bio-fertilizer and controls.

Sample	GGR	TDMP	LAR	LAI	NAR
Bio-fertilizer 10g	0.826 ± 0.06 [a]	8.19 ± 0.25 [a]	5.90 ± 0.31 [b]	1.3286 ± 0.12 [a]	0.00804 ± 0.0001 [a]
Bio-fertilizer 5g	1.271 ± 0.04 [a]	15.43 ± 1.12 [b]	13. 10 ± 0.75 [b]	3.7514 ± 0.23 [b]	0.01369 ± 0.0010 [a]
Bio-fertilizer 3g	1.096 ± 0.03 [a]	11.62 ± 0.36 [b]	8.60 ± 0.27 [b]	3.2325 ± 0.61 [a]	0.01156 ± 0.001 [a]
Chemical Fertilizer 3g	1.857 ± 0.05 [a]	24.34 ± 1.53 [b]	17.20 ± 1.43 [b]	5.3629 ± 0.85 [b]	0.03063 ± 0.001 [a]
Control	0.512 ± 0.02 [a]	6.61 ± 0.82 [a]	2.80 ± 0.15 [a]	1.1805 ± 0.06 [a]	0.00583 ± 0.0001 [a]

The values are expressed as mean ± standard error of mean (SEM) of replicate (n =3). Values with 'a' superscript in the same column do not differ significantly with the control ($p < 0.05$), whereas those with 'b' superscript in the same column differ significantly with the control ($p < 0.05$).

The growth parameters indicate that the application of the bio-fertilizer and chemical fertilizer significantly enhances plant growth and development compared to the control. The bio-fertilizer treatments, particularly 5g pots demonstrate significant improvements in the growth parameters. Similarly, the positive control demonstrates the overflowing effectiveness across all parameters, promoting the greatest growth rate, biomass production, leaf area development, and nutrient assimilation efficiency.

Equally, the nutrient composition uptake by the maize seedlings treated with various quantities of bio-fertilizer indicates reasonable uptake of the respective macronutrients. The results

indicated that the N, P, K 3g treatment is the most effective in enhancing the adsorption of the macronutrient by the plants. This treatment has consistently shown the highest values for all measured nutrients, demonstrating its efficacy in nutrient delivery and plant absorption over other treatments. 5g of the bio-fertilizer too showed considerable improvement in nutrient uptake, particularly N and P. This further demonstrate the potential of the produced bio-fertilizer as a viable alternative or complement to chemical fertilizer. In all the grams (3, 5 and 10) used, they enhanced nutrient uptake compared to the control.

Table 7
N, P, K nutrient composition uptake by the plant (adsorption capacity).

Fertilizer	Nitrogen (%)	Phosphorus (mg/100 g)	Potassium (mg/100 g)
Bio-fertilizer 10g	0.14 ± 0.05 [a]	0.052 ± 0.01 [a]	24.82 ± 1.34 [b]
Bio-fertilizer 5g	1.62 ± 0.08 [a]	0.78 ± 0.06 [a]	58.39 ± 2.75 [b]
Bio-fertilizer 3g	0.35 ± 0.02 [a]	0.41 ± 0.03 [a]	32.64 ± 1.83 [b]
Chemical Fertilizer 3g	1.89 ± 0.13 [a]	1.23 ± 0.17 [a]	83.45 ± 3.52 [b]
Control	0.11 ± 0.02 [a]	0.034 ± 0.02 [a]	10.52 ± 0.27 [a]

The values are expressed as mean ± standard error of mean (SEM) of replicate (n =3). Values with 'a' superscript in the same column do not differ significantly with the control ($p < 0.05$), while those with 'b' superscript in the same column differ significantly with the control ($p < 0.05$).

4. Discussion

4.1 Proximate and N, P, K Composition of Feedstock

The proximate composition analyses of the raw materials used, detailed their moisture content, ash content, lipid content, crude fiber, crude protein, and carbohydrate (CHO) content. The moisture content is relatively low across all samples, with chicken dropping exhibiting the highest moisture content (3.27%). This suggests that Chicken Dropping is more prone to microbial activity due to higher water content [26]. However, statistical analysis showed no significant difference ($p<0.05$) between the samples. The ash content, which indicates the total mineral content reflect a substantial inorganic residue, which might include essential minerals. In contrast, rice husk has the lowest ash content (2.59%), suggesting fewer minerals or non-combustible residues [27]. Zou and Yang [28] reported that rice husk is due composed of 18% ash, which is relatively more than what's obtained in this study. This difference could be attributed to several factors such as rice variety, soil chemistry, and even the geographic localization of the production [29].

The lipid content gives greater potential for energy storage in the form of fats. Rice husk has the lowest lipid content (0.62%), indicating it is a poor source of fat. The crude fibre, which represents the indigestible portion of plant material, is exceptionally high in rice husk (28.26%), indicating its primary composition as fibrous material. This high fibre content could make it a potential candidate for dietary fibre sources. The crude protein content was found to be significantly high in chicken dropping (24.63%), making it a rich source of nitrogenous materials, which is essential for animal feed and soil amendment. A similar study by Oyebamiji and Ayeni [30], reported that secondary raw material of poultry and livestock enterprises contains a sufficient number of nutrient elements that are a valuable raw material for producing highly effective fertilizers. Carbohydrate content in the raw materials indicate a significant energy source from sugars and other carbohydrates.

Rice husk was recorded with the highest N content. This aligns with its protein content, indicating its potential use as a nitrogen-rich fertilizer. Higher nitrogen content is attributed to substantial presence of nitrogenous compounds, which could be indicative of protein or other

nitrogen-rich organic molecules [20]. Jain, Choudhary [29], reported that rice husk do improve nitrogen and other macro and microelements absorption which enhance the production and translocation of the dry matter content from source to sink. Further, phosphorus is crucial for energy transfer and genetic material in plants, so chicken dropping could significantly enhance soil fertility. Studies have reported chicken manure to be high in organic contents. Similarly, in the present study chicken dropping was found to have the highest phosphorus and potassium content [31]. Such manure contains nutrients that are essential for plant's growth, such as calcium, magnesium, Sulphur, manganese, copper, zinc, iron, boron and molybdenum [21].

4.2 Microbial Counts of the Digest

The results of the biochemical tests imply the potential of the substrate combined and predict the possible influence of the soil microbial communities in converting waste-to-wealth. Prior to the digestion, the bio-digester substrates showed moderate microbial counts, with a higher CFU/g at lower dilutions (10^{-1}, 10^{-5} and 10^{-10} having CFU/g of 215, 143 and 27 respectively), thus indicating a significant presence of microbial colonies. Some bacteria were considered pathogenic including *Salmonella* species*, Klebsiella* species, *Bacillus, Clostridium* and *Proteus* species. After digestion, there is a notable increase in microbial counts, thus, indicating a proliferation of microbial colonies. The fungal species list expanded to include *Aspergillus* alongside *Rhizopus* and *yeast* cells. This suggests that the digestrate provided a conducive environment for microbial growth, leading to a higher density of microbial settlement. The diversity of the microbes increased post-digestion, as well bespeak that the conversion process (waste to fertilizer) facilitates the emergence of other microorganisms. Moreover, the microbial counts and its diversity highlighted on the bio-digester's role in creating a nutrient-rich environment that is conducive to microbial proliferation [17].

4.3 N, P, K Composition of the Digestrate

The compost mixture after digestion showed a substantial N, high P, and an exceptionally high K content. Concentration of the N has increased in the mixture compared to the individual raw material, while P content in the mixture is lower than in the chicken dropping, which is likely due to dilution from the other components. The K content in the compost is significantly higher than in the any individual component before the digestion. This indicates a substantial increase in potassium concentration through the digestion process. In comparison, the high nutrient concentrations obtained in the compost mixture imply its potential as a potent soil amendment, providing a rich source of N, P, and K [21, 31].

From the results obtained, it it observed that the digestion process has significantly enhanced the nutrient compactness of the compost, even though, the effectiveness of nutrient transfer to the soil requires further investigation to optimize the procedure for improving agricultural productivity.

4.4 Plant Response to the Bio-fertilizer and Adsorption Capacity

TDMP an indicator of the overall biomass accumulated was highest in plants treated with 5g bio-fertilizer showing a modest increase. LAR that reflects the leafiness of the plant is highest for the 3g treatment, indicating extensive leaf development. All the bio-fertilizer treatments promote leaf development. Importantly, the produced bio-fertilizer indicated substantial increases in LAI compared to the control. NAR, an indicator of the efficiency of plants in converting absorbed nutrients into biomass also showed significant improvements in the studied plant. The growth

parameters indicates that application of the bio-fertilizer and chemical fertilizer significantly enhances plant growth and development compared to the control. This has really suggest the potential of the bio-fertilizer as effective alternatives to conventional chemical which affect the natural microbial community and causing soil infertility [32, 33].

Nutrient uptake is crucial in plant growth and it determines the impact of every fertilizer applied, as well determine its development potential. Both treatments significantly enhance N uptake compared to the control. Phosphorus uptake is highest indicating superior phosphorus adsorption capacity of the maize plant, while K indicates the most effective adsorption [23, 31, 33]. Notable, the 5g bio-fertilizer demonstrate considerable improvement in nutrient uptake, particularly N and K, which makes it a potential and viable alternative to chemical fertilizer. However, 3g and 10g also enhance nutrient uptake compared to the control, though to a lesser extent.

5. Conclusions

The degradation of orange waste, chicken droppings and rice husks by nitrogen fixers was demonstrated in anaerobic digester in order to produce biofertilizer. This process yielded substantial amounts of N, P and K in the resulting biofertilizer. This shows that the digestion process concentrates these elements, making the mixture a rich source of essential nutrients for soil enrichment. The presence of *Pseudomonas, Clostridium* and *Proteus* species confirmed that the nutrient and elemental content of the resulting mixture was increased by their activity to produce a biofertilizer. Growth parameters revealed that the biofertilizer significantly enhances plant growth, development and nutrient assimilation. The 5 g treatment showed the most significant improvements in growth parameters, suggesting that the small amount of the mixed wastes increases microbial activity for enriching the biofertilizer with adequate nutrient, and its potential as an effective soil fertility enhancer. This would promote plant growth, leaf area development and nutrient assimilation efficiency. Therefore, Further research should focus on optimizing the ratio of mixed waste, fermentation time and selected microbial inoculants with higher nutrient supplementation ability, in order to determine the optimal concentrations of the respective raw materials for maximizing yield in many crops.

Conflict of Interest Statement

This is an example “The authors declare that there is no conflict of interest regarding the publication of this paper. No financial support, grants, or other forms of compensation were received that could have influenced the outcomes of this work. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

[1] Sjah T, Zainuri Z. Agricultural supply chain and food security. Zero Hunger: Springer; 2020. p. 79-88.
[2] Jayne TS, Sanchez PA. Agricultural productivity must improve in sub-Saharan Africa. Science. 2021;372(6546):1045-7.
[3] Giller KE, Delaune T, Silva JV, Descheemaeker K, van de Ven G, Schut AG, et al. The future of farming: Who will produce our food? Food Security. 2021;13(5):1073-99.
[4] Tully K, Sullivan C, Weil R, Sanchez P. The state of soil degradation in Sub-Saharan Africa: Baselines, trajectories, and solutions. Sustainability. 2015;7(6):6523-52.
[5] Nadarajan S, Sukumaran S. Chemistry and toxicology behind chemical fertilizers. Controlled Release fertilizers for sustainable agriculture: Elsevier; 2021. p. 195-229.
[6] Tadesse A, Hailu W. Causes and Consequences of Land Degradation in Ethiopia: A Review. International Journal. 2024;10(1):10-21.

[7] LUMULA GA. Determination of Soil Fertility Index Parameters and Speciation of Potassium and Molybdenum in Soils from Selected Farms in Kakamega County. Kenya Retrieved from https://ir-library ku ac ke/bitstream/handle/123456789/22753/Determination of Soil Fertility pdf. 2021.
[8] Kaur P, Purewal SS. Biofertilizers and their role in sustainable agriculture. Biofertilizers for sustainable agriculture and environment. 2019:285-300.
[9] Sharma B, Tiwari S, Kumawat KC, Cardinale M. Nano-biofertilizers as bio-emerging strategies for sustainable agriculture development: Potentiality and their limitations. Science of The Total Environment. 2023;860:160476.
[10] Lim S-F, Matu SU. Utilization of agro-wastes to produce biofertilizer. International Journal of Energy and Environmental Engineering. 2015;6:31-5.
[11] Hassaneen FY, Abdallah MS, Ahmed N, Taha MM, Abd ElAziz SMM, El-Mokhtar MA, et al. Innovative nanocomposite formulations for enhancing biogas and biofertilizers production from anaerobic digestion of organic waste. Bioresource technology. 2020;309:123350.
[12] Singh S, Hariteja N, Sharma S, Raju NJ, Prasad TR. Production of biogas from human faeces mixed with the co-substrate poultry litter & cow dung. Environmental Technology & Innovation. 2021;23:101551.
[13] Dahunsi S, Oranusi S. Co-digestion of food waste and human excreta for biogas production. 2013.
[14] Ezejiofor T, Eke N, Okechukwu R, Nwoguikpe R, Duru C. Waste to wealth: Industrial raw materials potential of peels of Nigerian sweet orange (Citrus sinensis. African Journal of Biotechnology. 2011;10(33):6257-64.
[15] Lambu Z, Shamsuddeen U, Yahaya S, Aliyu A, Karfi A, Isyaku J, et al. Production of Bio-Fertilizer through Composting of Tannery Wastes with Cow-Dung and Rice Bran. UMYU Journal of Microbiology Research (UJMR). 2021;6(1):1-10.
[16] Ángel Siles López J, Li Q, Thompson IP. Biorefinery of waste orange peel. Critical reviews in biotechnology. 2010;30(1):63-9.
[17] Hassan DU, Abdulsalam S. Assessement of bio-fertilizer quality of anaerobic digestion of watermelon peels and cow dung. Chemical and Biomolecular Engineering. 2017;2(3):135-41.
[18] Helrich K. Association of official analytical chemists. Official methods of analysis of the Association of Official Analytical Chemists, 15th ed Washington, DC: Arlington, VA. 1990.
[19] Sahu O, Abatneh Y. Study of biodigester design for fuel and fertilizer. Int J Sustain Green Energy. 2013;2(4):147-52.
[20] Abbas M, Atiq-ur-Rahman M, Manzoor F, Farooq A. 03. A quantitative analysis and comparison of nitrogen, potassium and phosphorus in rice husk and wheat bran samples. Pure and Applied Biology (PAB). 2012;1(1):14-5.
[21] Fokom WD, Tendonkeng F, Azangue GJ, Miégoué E, Djoumessi F-GT, Kwayep NC, et al. Effects of different levels of fertilization with hen droppings on the production and chemical composition of Pennisetum clandestinum (Poaceae). Open journal of animal sciences. 2021;11(4):543-58.
[22] Olarinoye I, Sharifat I, Kolo MT. Heavy metal content of soil samples from two major dumpsites in Minna. 2010.
[23] Farnia A, Torkaman H. Effect of different biofertilizers on yield and yield components of maize (Zea mays L.). Bull Environ Pharmacol Life Sci. 2015;4(4):75-9.
[24] Ennab H. Effect of Organic Manures, Biofertilizers and NPK on Vegetative Growth, Yield, Fruit Quality and Soil Fertility of Eureka Lemon Trees (Citrus limon (L.) Burm). Journal of Soil Sciences and Agricultural Engineering. 2016;7(10):767-74.
[25] de Matos Nascimento A, Maciel AM, Silva JBG, Mendonça HV, de Paula VR, Otenio MH. Biofertilizer application on corn (Zea mays) increases the productivity and quality of the crop without causing environmental damage. Water, Air, & Soil Pollution. 2020;231:1-10.
[26] Muhammad F, Musa D, Buah J. PRODUCTION OF BIOFERTILIZER USING GOAT DUNG, CHICKEN DUNG, PINEAPPLE PEELS AND CITRUS PEELS. FUDMA JOURNAL OF SCIENCES. 2023;7(5):173-5.
[27] Erugo AI, Sunday K, Olusesi FY. Optimization of Bio-fertilizer Production From Watermelon Peels Using Response Surface Methodology. 2022.
[28] Zou Y, Yang T. Rice husk, rice husk ash and their applications. Rice bran and rice bran oil: Elsevier; 2019. p. 207-46.
[29] Jain A, Choudhary AK, Jha J. Influence of rice husk ash on the swelling and strength characteristics of expansive soil. Geotechnical and Geological Engineering. 2020;38(2):2293-302.
[30] Oyebamiji KJ, Ayeni L. Proximate composition of African eggplant (Solanum macrocarpon) obtained from soil amended with cattle dung and poultry manure. FUW Trends in Science & Technology Journal. 2018;3(2B):981-84.
[31] Singh G, Shamsuddin M, Lim S, editors. Characterization of chicken manure from manjung region. IOP conference series: materials science and engineering; 2018: IOP Publishing.

[32] El-Sherbeny T, Mousa AM, Zhran MA. Response of peanut (Arachis hypogaea L.) plant to bio-fertilizer and plant residues in sandy soil. Environmental Geochemistry and Health. 2023;45(2):253-65.

[33] Beyranvand H, Farnia A, Nakhjavan S, Shaban M. Response of yield and yield components of maize (Zea mayz L.) to different bio fertilizers. International journal of Advanced Biological and Biomedical Research. 2013;1(9):1068-77.