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PRODUCTION AND CHARACTERIZATION OF BIOFERTILIZER FROM CHICKEN FEATHER

Oko William Chibuzor*[1], Eze Kenneth Afamefuna[2], Chukwu Tobechi[3]
1. Department of Chemical Engineering Institute of Management and Technology, Enugu.
2. Department of Chemical Engineering Enugu State University of Science and Technology
3. Department of Chemical Engineering Caritas Amorji –Nike, Enugu, Enugu State.

Author for Correspondence: Oko William Chibuzor; **Email:** Okohwilliam333@gmail.com

Abstract - In this research, biofertilizer was produced by co-digesting chicken feathers and sawdust using micro-organisms. A 10-liter capacity laboratory bio-digester was used for the study. The proximate analysis of feedstock was done. Micro-organisms were isolated from cow dung using nutrient agar. Temperature, pH, organic matter, carbon, nitrogen, phosphorus, and potassium were monitored at intervals till the end of degradation. The end product (slurry) of composting was further evaluated for efficacy and effectiveness as an organic fertilizer in the field. The physio-chemical analysis of the macro elements was Nitrogen 2.52g/l, phosphorus 0.16g/l, and potassium 0.37g/l. The proximate analysis reveals that the C: N ratio of chicken feathers and sawdust was 4:1 and 160:1 respectively. The process parameter study shows that the maximum yield of nitrogen, phosphorous, and potassium was obtained with 1: 1 ratio of chicken feather and sawdust at a temperature of 55 ^{o}C, time of 22 days, and pH of 7.3. The plant tested in the field was beans and it showed high growth parameters such as deep green color and high number of leaves.

Keywords: Chicken feather, bio fertilizer, characterization, Hydrolysis

1. Introduction

Fertilizers are natural or artificial substances that contain some chemical elements that improve the growth and productivity of plants. It enhances the soil's natural fertility or replaces the chemical elements taken from the soil by previous crops. Fertilizers may be distinct from liming materials or other non-nutrient soil amendments. The three main macronutrients of fertilizers are Nitrogen (N), phosphorus (P), and potassium (K) with the occasional addition of supplements like rock dust for micro-nutrients. They exist in different forms such as dry, pelletized, and liquid, and are applied with large agricultural equipment or hand tools.

Chicken feathers are byproducts of poultry processing industries considered a potential source of high protein supplements owing to their crude protein content of more than 85%. Poultry feathers constitute up to 10% of total chicken body weight (Qingxin, 2019), feathers have been classified as waste because of the lack of effective recycling methods.

Chicken feathers that are mostly disposed of around poultry industries or slaughterhouses have resulted in serious environmental problems. The enormous keratin waste leach and contaminate the underground water (Kumar et al., 2017), Cause methane production (Wang et al., 2015) microplastics (Chen et al., 2020) and pathogens spread such as avian influenza (Kim et al., 2017) and salmonella (Lee et al 2018). The quest to control the environmental problems caused by the chicken feather has led to the development of many technologies for the conversion of keratinous waste to useful products (Pettett and Kurtboke 2004).

The bioconversion of keratin waste material by enzymatic digestion is preferred over thermal hydrolysis in dilute acid or base because the treatment does not require significant energy and cannot destroy amino acid instead it will add living organisms that colonize the rhizosphere of plants and promotes growth (Vessey, 2003).

Production of biofertilizer from chicken feathers has become globally attractive because of its importance in fostering food security and cleaning the environment. Bio fertilizer is a substance which contains living microorganisms which, when applied to soil add nutrients to the host plant through the natural processes of nitrogen fixation and solubilizing phosphorus. Bio fertilizers produced by the anaerobic digestion of organic matter or waste involves four phases of digestion which include hydrolysis, acidogenesis, acetogenesis and methanogenesis.

2.0 Literature Review

2.1 Introduction to Biofertilizers

Biofertilizers are natural fertilizers enriched with living microorganisms that enhance plant growth by increasing the availability of essential nutrients. They serve as eco-friendly alternatives to synthetic fertilizers, playing a crucial role in sustainable agriculture by reducing environmental pollution and improving soil health (Reddy et al., 2021). The growing adoption of biofertilizers is driven by the need to mitigate the adverse effects of chemical fertilizers, such as soil degradation, water contamination, and greenhouse gas emissions.

2.2 Chicken Feather as a Biomaterial

Chicken feathers are abundant agricultural by-products predominantly composed of keratin, a resilient fibrous protein (Ramakrishnan et al., 2020). The global poultry industry generates millions of tons of feathers annually, creating substantial waste management challenges. Traditionally discarded or converted into low-value products like animal feed, chicken feathers are now recognized as a promising raw material for biofertilizer production due to their high nitrogen content and biodegradable properties.

2.3 Biodegradation of Chicken Feathers for Biofertilizer Production

The primary obstacle in utilizing chicken feathers is the degradation of keratin, which necessitates specific microbial or enzymatic processes. Studies have investigated keratinolytic microorganisms, such as *Bacillus subtilis*, *Pseudomonas aeruginosa*, and *Streptomyces* species, to break down keratin into simpler forms usable by plants (Sharma & Gupta, 2016). Enzymes like keratinase facilitate this conversion, producing amino acids, peptides, and other organic compounds beneficial for soil fertility.

2.4 Characterization of Biofertilizer

The characterization of biofertilizers includes the analysis of their chemical composition, nutrient levels, and microbial activity. Chicken feather-based biofertilizers are rich in nitrogen, a vital nutrient for plant growth, and may also contain phosphorus, potassium, and trace elements (Kumar et al., 2019). Techniques such as spectrophotometry, chromatography, and microbial assays are used to assess the efficacy and suitability of these biofertilizers for different crops and soil types.

2.5 Benefits of Chicken Feather-Derived Biofertilizers

Chicken feather-derived biofertilizers offer several benefits:

1. **Nutrient Recycling:** They provide an efficient method for recycling nitrogen and other nutrients into agricultural systems.
2. **Waste Management:** Utilizing chicken feathers helps reduce environmental waste and limits the burden on landfills.
3. **Soil Health:** These biofertilizers enhance soil structure, boost microbial activity, and improve nutrient availability, fostering long-term agricultural productivity.

2.6 Challenges in Biofertilizer Production

Despite their potential advantages, the production of biofertilizers from chicken feathers faces several challenges:

1. **Processing Efficiency:** The effective degradation of keratin requires optimized microbial or enzymatic treatments, which can increase production costs.

2. **Scalability:** Scaling up from laboratory-based processes to industrial-scale production presents technical and economic difficulties.
3. **Market Acceptance:** Farmers may be reluctant to adopt biofertilizers due to limited awareness and higher initial costs compared to conventional fertilizers.

2.7 Recent Advances in Biofertilizer Research

Recent advancements have focused on improving the efficiency of chicken feather degradation through genetic engineering of keratinolytic microorganisms and the development of cost-effective enzymatic processes (Park et al., 2022). Combining biofertilizers with other organic amendments, such as compost or manure, has shown promising results in enhancing crop yields and soil quality. The production and characterization of biofertilizers from chicken feathers offer a sustainable solution for agricultural challenges. Although progress has been made in keratin degradation and nutrient recycling, further research is necessary to address scalability, cost-effectiveness, and market adoption. This approach aligns with global efforts to promote circular economy practices and minimize the environmental impact of agricultural activities.

3.0 Materials and Methods

3.1 Materials

The following materials were used in doing the research. Chicken feather gotten from slaughterhouse at Ogbete Main Market Enugu, Sawdust from timber shed Uwani Enugu South Local Government, Water from the laboratory, and cow dung from Garriki Cow slaughterhouse, 10 liters capacity laboratory bio digester, Electric Oven, Atomic Absorption Spectrophotometer (AAS), pH meter, Methanol. All the chemicals and reagents used in analysis were of analytical grade and supplied by Conraws, Nigeria LTD, Enugu.

3.2 Methods

The block diagram of the production is shown in Figure 3.1

3.2 Methods: Block Diagram Overview

The block diagram in Figure 1 outlines the sequential steps involved in the production of biofertilizer from chicken feathers. It provides a visual representation of the processes and materials utilized, ensuring a clear understanding of the workflow.

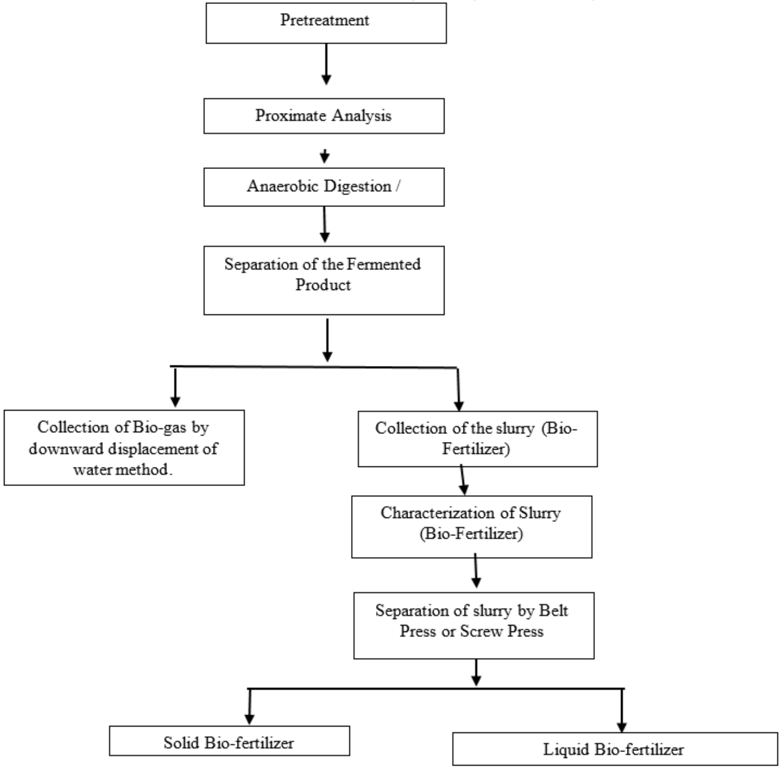

Fig 1 Block Diagram of the Production process

Explanation of the Block Diagram

1. **Pretreatment:** Raw materials, such as chicken feathers, undergo cleaning and preconditioning to remove impurities and enhance their suitability for degradation. This step ensures efficient microbial or enzymatic activity during subsequent processes.
2. **Proximate Analysis:** The chemical composition of the raw materials, including moisture content, nitrogen levels, and other nutrients, is analyzed to determine their suitability for biofertilizer production.
3. **Anaerobic Digestion:** The pretreated materials are placed in an anaerobic digester, where microbial activity breaks down the organic matter, producing biogas and a nutrient-rich slurry.
4. **Separation of the Fermented Product:** The digested mixture is separated into solid and liquid components. This step simplifies the collection and characterization of the resulting biofertilizer.
5. **Collection of Biogas:** Biogas generated during anaerobic digestion is collected using the downward displacement of water method, which captures the gas for potential energy applications.
6. **Collection of the Slurry (Bio-Fertilizer):** The slurry, a by-product of the digestion process, is collected for further processing. It is nutrient-rich and forms the base for the final biofertilizer.
7. **Characterization of Slurry (Bio-Fertilizer):** The slurry is analyzed for its chemical composition, including nitrogen, phosphorus, potassium, and other essential nutrients, to assess its suitability for use as a biofertilizer.
8. **Separation of Slurry by Belt Press or Screw Press:** The slurry is mechanically separated into solid and liquid fractions using equipment like a belt press or screw press. This step produces distinct solid and liquid biofertilizer products.
9. **Solid Bio-Fertilizer and Liquid Bio-Fertilizer:** The solid fraction is packaged as a solid biofertilizer, while the liquid fraction is collected and stored for use as

a liquid biofertilizer. Both products offer versatile applications in agriculture, improving soil fertility and crop productivity.

This systematic process ensures the efficient utilization of raw materials to produce high-quality biofertilizers while capturing biogas as an additional resource.

3.2.1 Proximate analysis of the feedstocks (Chicken Feather and Saw Dust)

The proximate analysis of the saw dust and chicken feather powder samples obtained as described by Cioabla *et al.* (2012) and Manyi-loh *et al.* (2015) with slight modifications.

3. 2. 2. Pretreatment and charging of raw material into the biodigester

Chicken feather was thoroughly washed with detergent and defatted with methanol to make it fat-free. It was placed in an evaporator to remove the solvent and washed three to four times again with warm water and air dried at room temperature, then oven dried at a temperature of 105°C. The feather was ground to a particle size of 2mm.

3.2.3 Anaerobic digestion

Feather meal was used and mixed uniformly with sawdust in a 1:1 ratio (feather mill: sawdust). It was placed in a10 10-liter capacity laboratory biodigester and autoclaved at 120°C for 15 minutes. Talboys, et al., (2015). Each batch of the mixture contains 1000gram (1kg) of feedstock mixture in a 1:1 ratio (500gm of a chicken feather: 500gm of sawdust) to 7 liters of clean water and 175gram (0.175kg) of cow dung (inoculums) and 3% of the consortium was charged into the biodigester, mixing was achieved by agitation and stirring. The degradation was observed through the flame test. The flame was used to detect how degradation was going on. The optimum time was achieved on the 22nd day, at a pH of 7.30, and a temperature of 55°C the flame test continued until it reduced significantly which shows that the conversion process has been exhausted and depletion of biogas occurred. The flame reduced significantly on the 25th day with a measure of substrate at 70% chicken feather to 30% sawdust) at pH of 7.8, a temperature of 47°C after which no appreciable production occurred from biochemical conversion of the slurry.

3.2.4 Phase separation

The biofertilizer produced from the feedstock was subjected to a purification process as described by Wellinger and Lindberg, (2005). After the anaerobic digestion, the volume of the raw biogas stream produced was obtained using the downward displacement of water. This was achieved by filling a 1000ml calibrated transparent conical flask with water and crystal violet color added to aid in reading the volume, the conical flash was converted or tight with a stopper which has two holes, with one end of the holes connecting to the gas outlet pipe and the other end to be a 1000ml calibrated glass measuring cylinder. The quantity of the biogas was obtained by reading the volume of water displaced by the gas into the measuring cylinder as the top of the digester was turned on. The displaced water was measured to represent the volume of biogas produced. After the biogas removal through the downward displacement of water method. The secondary digestate (slurry) was collected and characterized. Then the digestate (bio-fertilizer) normally in slurry form (liquid and solid) was separated using screw press and belt press separation method. The liquid digestate in the liquid phase contains more soluble forms of materials like phosphorus, nitrogen, and potassium. The solid digestate which involves dry matter, volatile solids, carbon, phosphorus, potassium, and nitrogen was significantly accumulated in the solid phase. The solid phase was concentrated using an evaporation process (sun drying) and stored as organic solid fertilizer. The products were analyzed and stored for use.

3.2.5 physio-chemical analysis of the digestate

A.O.A.C (1992) methods of analysis were applied in the determination of the trace elements such as phosphorus (P), Nitrogen (N), Aluminum (Al), Calcium (Ca), magnesium (mg), Sodium (Na), Potassium (K), manganese (Mn), Zinc (Zn), Copper (Cu), and Iron (Fe).

3.2.6 Effect of the Process Parameters

Effect of Temperature on the biofertilizer yield (NPK)

The effect of temperature on the bio fertilizer yield was investigated by weighing 1 kilogram of the feedstock (comprising 500 grams of chicken feather and 500 grams of sawdust) combined with 7 liters of clean water into a 10liter bio digester. An addition of 175 grams (0.175 kg) of cow dung served as the microbial inoculum, introducing beneficial bacteria to kick start the anaerobic digestion process. Furthermore, 3% of a microbial consortium was added to enhance the degradation of the feedstock. Agitation and stirring were utilized to ensure thorough mixing of the components in the bio-digester. The progression of degradation within the bio-digester was monitored at temperatures of 20°C, and 40°C. 60°C and 80°C, a constant pH of 7.3, and a time of 20 minutes.

Effect of Time on the Biofertilizer Yield (NPK)

The experimental setup is similar to that of the determination of the effect of temperature was used. The degradation of the chicken feather and saw dust consortium were monitored at times 10, 20, 30 40, and 50 minutes at a constant temperature and pH of 60°C and 7.3 respectively.

Effect of pH on the biofertilizer yield (NPK)

The effect of pH on the biofertilizer yield (NPK) was determined with a similar experimental setup as that of time. The degradation of the chicken feather and saw dust consortium was monitored at pH 7.0, 7.2, 7.4, and 7.6, at a constant temperature and time of 60°C and 50 minutes respectively.

4.0 Results and discussions

4.1 **characterization of the samples of the substrates**

Table 1Proximate composition of chicken feather and sawdust

Raw materials (Feedstock)	Chicken feather	Sawdust
Moisture (%)	2.56±0.09	5.54±0.06
Dry matter (%)	7.18±0.04	5.65±0.05
Ash (%)	1.56±0.095	20.45±0.05
Volatile solid (%)	16.50±0.5	13.80±0.2
Carbon (%)	57.10±0.5	54.20±0.1
Nitrogen (%)	14.10±0.05	0.36±0.015
C: N ratio	4:1	160:1

The analysis showed that there was more moisture in sawdust than in chicken feathers, but volatile solid content was higher in chicken feathers than in sawdust. The complex media sources showed that sawdust and the chicken feather had a carbon-nitrogen ratio (C: N) of 4:1 and 160:1 respectively. This proximate composition of sawdust and chicken feather showed that sawdust has high carbon and volatile solid content and low nitrogen content while chicken feather has high carbon and high nitrogen content. The results of the proximate composition of the chicken feather and sawdust testified that the use of 100% sawdust in anaerobic digestion might result in tended fermentation due to poor nitrogen content of sawdust while excess nitrogen content in chicken feather might result in ammonia inhibition.

The need therefore arises to blend the two substrates to ensure that the missing nutrient in one substrate is supplied by the other substrate thereby maintaining nutrient balance.

4.2 The physiochemical analysis of the feather digestate.

Table 2: Physiochemical Analysis of Digestate

Parameter	pH	Electrical conductivity	Total solids	P	N	Al	Ca	Mg	Na
Unit		**dsm^{-1})**	**g/l**	**g/l**	**g/l**	**g/l**	**g/l**	**g/l**	**mg/l**
Result	7.3	**0.4**	**18.2**	**0.16**	**2.52**	**9.8**	**0.93**	**0.78**	**0.32**

Parameter	**K**	**Mn**	**Zn**	**Cu**	**Fe**
Unit	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Result	**0.37**	**0.60**	**145.3**	**90.3**	**1.60**

The results showed that the biofertilizer produced is rich in micronutrients which are needed for plant growth as can be seen by the presence of primary, secondary, and trace or micro-nutrients in varying proportions.

4.3 **Effect of the process parameters**

Influence of Temperature on nitrogen yield

The consortium of the organisms on the yield of nitrogen from the substrate ratio was demonstrated as shown in Fig. 2 to 4 below. The effect of the organisms on yield or solubilization of phosphorus and potassium was also shown in Fig. 3 to 4.

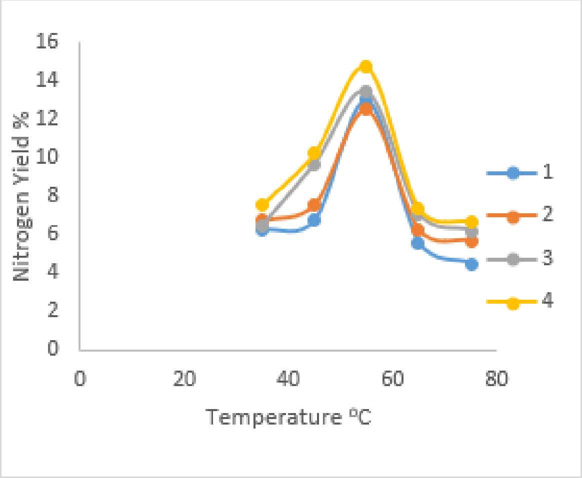

Fig 2 Effect of Temperature on Nitrogen Yield during composting

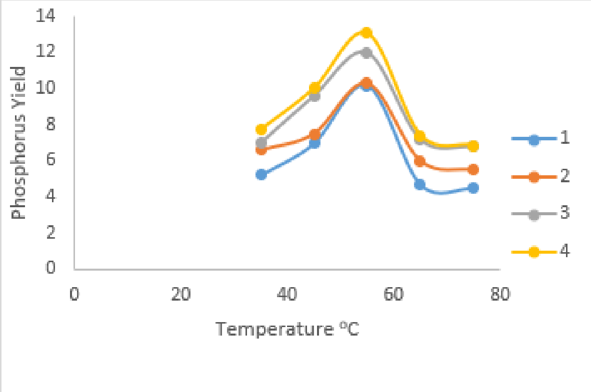

Fig 3 Effect of Temperature on Phosphorus Yield during composting

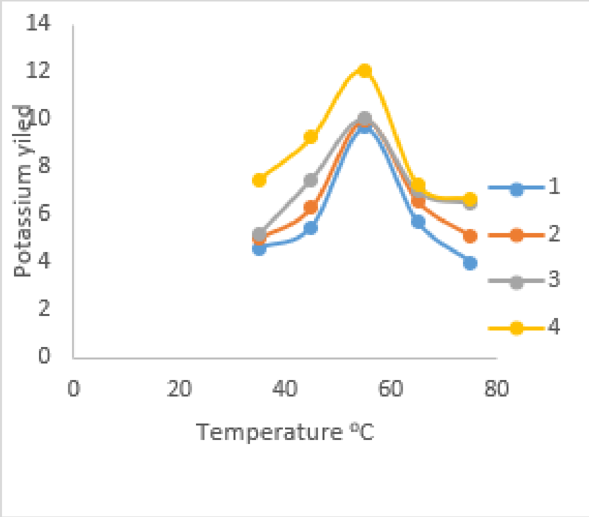

Fig 4 Effect of Temperature on Potassium Yield during composting

It was observed that all the graphs showed the same trend for the yield of nitrogen. The highest percentage yield of nitrogen was obtained at temperature of 55^{0}C from the substrate ratio 1:1 and with consortium 4. This agrees with report by Edriss*et al* (2006), that composting with equal substrate ration and combined organisms with different Capacity to produce nutrients has a greater influence on the yield of nitrogen. Solubilization of phosphorus and potassium by the microorganisms varies with the subtract ration. All the consortium showed a good potential in solubilizing phosphorus and potassium. Consortium 4 was more active in all nutrients. After comparing the results of this investigation with other reviewed work, it was observed that the use of consortium of organisms improved nutrient yield.It shows that the nature and population size of microorganism in the hydrolysis depend on temperature. A similar result was obtained by (Lyndall*et al*, 2004).

Effect of Time

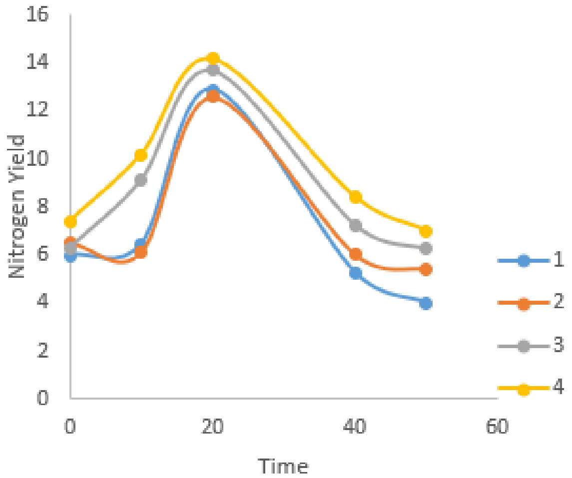

Fig 5 Effect of Time on Nitrogen Yield during composting

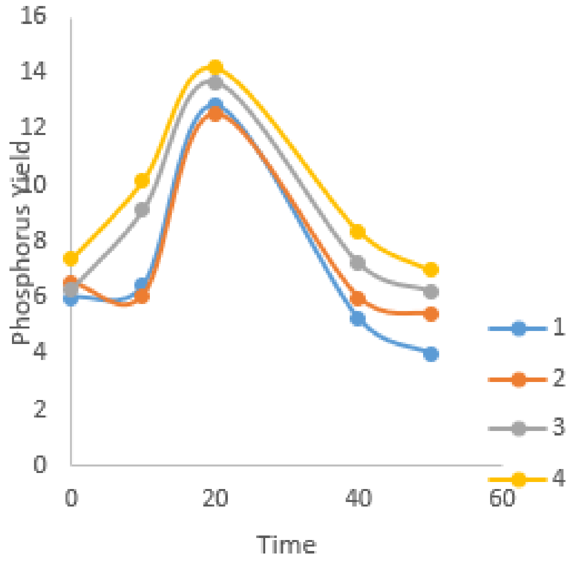

Fig 6 Effect of Time on phosphorus Yield during composting

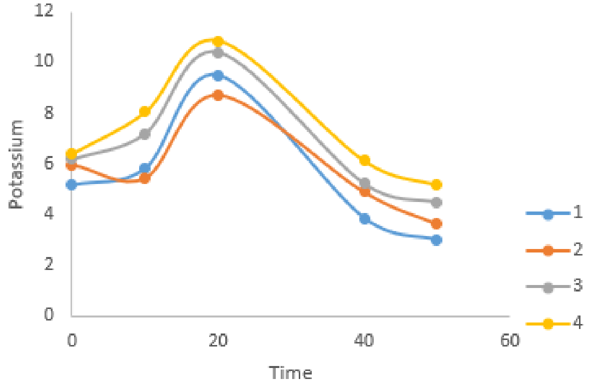

Fig 7 Effect of Time for Potassium Yield During Composting

The effect of time on nutrient yield. It was observed that mineralization of nitrogen and solubilization of phosphorus and potassium increased with increase in time. The substrates content (chicken feather and saw dust) decreased with increase in number of days. As hydraulic retention time increased from zero days to 25 days, there was a gradual increase in the yield of nutrients. The optimum yield occurred at 22nd day reaction time by consortium 4 giving the highest yield followed by 3, 2, 1 indicating that longer time of degradation above 25 days lead to reduction in organic matters and enzyme population. A similar result was obtained by (Shell *et al*, 2003).

This showed that the speed of degradation was greater with consortium 4, the organic matter decomposes at various speed at several temperature in which microorganism plays role. This agrees with the report by Adeline and Ka, (2014).

Effect of pH

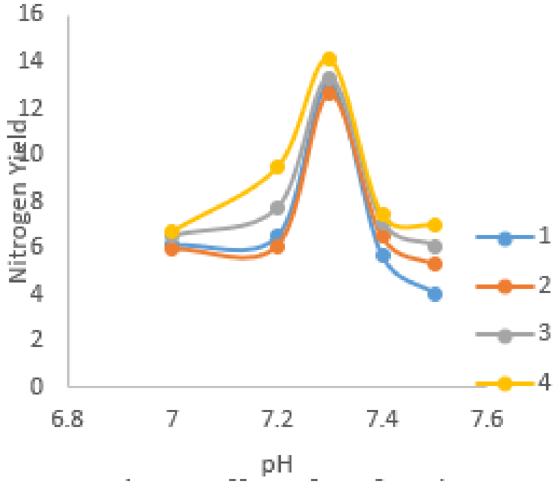

Fig 8 Effect of pH for Nitrogen Yield During Composting

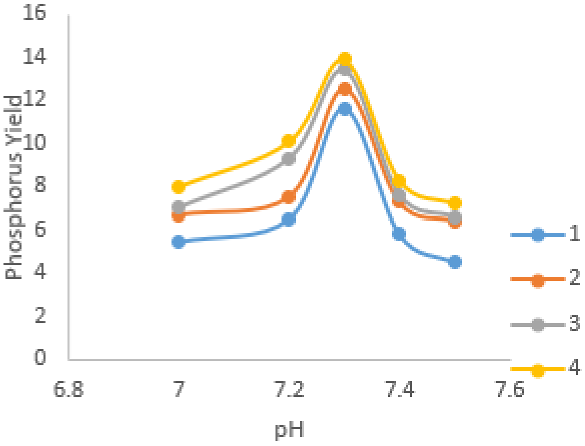

Fig 9 Effect of pH for Phosphorus Yield During Composting

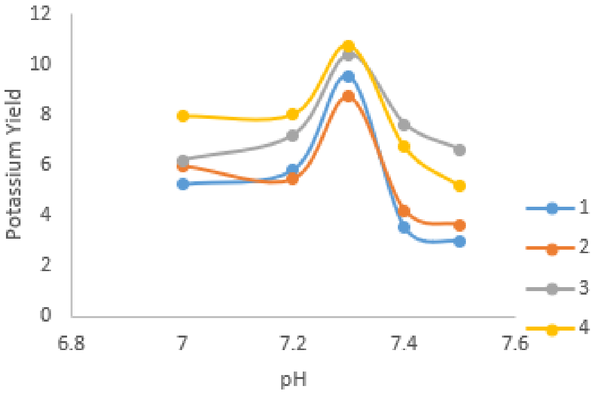

Fig 10 Effect of pH for Potassium Yield During Composting

The yield of nitrogen and solubilization of phosphorus and potassium was low during the processing period. The change in pH of the composts as observed during composting, initial pH value of 7.0 the nutrient yield was low. There was an optimum attainment of yield at pH value of 7.30 and remain like that until pH value of 7.5 a quick drop in nutrient yield. It indicates that the highest degrading activity occurred at pH 7.30, and there was a gradual decrease in nutrient yield above pH 7.30. Similar results were reported by Fang and Wong, (1999) and Bernal *et al* (1997) that the range of pH values suitable for bacteria development is in the range 6.0-7.5.

The Field tests of the bio fertilizer

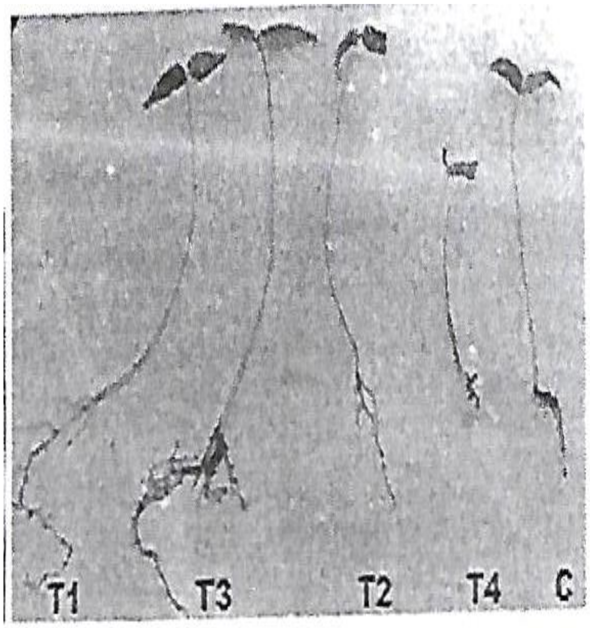

Fig 11 Field Test on the effect the biofertilizer on growth

The effect of biofertilizer on control (untreated plant) and treated plants is shown in fig 4.10. After a week of observation of seed germination, it became evident that plants in the T3 treatment group, which received a co-digested mixture of chicken feathers and sawdust at a 50% to 50% ratio, showed superior growth parameters compared to the other groups. Notably, plants treated with the co-digested substrates also exhibited a richer green color compared to the control group, with the T3 group showing the most pronounced greenness. This enhanced coloration suggests an improved nitrogen availability, as the yellowish-green hue observed in the control plants (T0) typically indicates nitrogen deficiency, a point corroborated by the findings of Silas et al. (2012). Furthermore, the T3 treatment group also recorded the highest number of leaves per plant, suggesting a potential for increased yield.

5.0 Conclusion

The result of the research has shown that co-digestion of chicken feathers and sawdust at a ratio of 1:1 are good sources of bio-fertilizer by enzyme hydrolysis. Compositing of chicken feathers and sawdust with microbial inoculums produced a good bio-fertilizer as regards to mineralization of soil nutrients (nitrogen, phosphorus, and potassium). The microbial must be in the consortium to produce a better yield. The use of a consortium of organisms reduced the long time needed to break down the resisting or tough components of the substrates. It also increased the rate of mineralization of N.P.K. Chicken feather and sawdust were found to be a better source of the response variable (N.P.K) after comparing the result of the characterization of bio-fertilizer produced with the literature review. Cow dung was found to be a good source of micro-organisms (enzymes) which enhanced the mineralization of nitrogen, phosphorus, and potassium during composting. The application of treated chicken feathers and sawdust in the soil as biofertilizers significantly increased the agronomic parameters of plants.

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