DETERMINATION OF BIOFERTILIZER QUALITY (NPK), CALCIUM AND MAGNESIUM OF DIGESTATE OF LAYING BIRDS DROPPINGS CO-DIGESTED WITH BROILER BIRDS DROPPINGS IN A 30:70 RATIO

Abdullateef, A.I.[1*], Hope, N.B.[2], Alfa, M.I.[3] and Okpanachi, U.[4]
[1,2,4]*Department of Animal Production, Faculty of Agriculture, University of Jos, Plateau State, Nigeria*
[3]*Department of Civil Engineering, Faculty of Engineering, University of Jos, Plateau State, Nigeria*
Corresponding author:* hakolahwohle34@gmail.com; *+2349068628463*

ABSTRACT
This study evaluated the nutrient quality of biofertilizer produced from the anaerobic co-digestion of laying birds' droppings and broilers' droppings in a 30:70 ratio. The primary focus was on the concentrations of essential nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Analytical methods were used to compare the nutrient profiles of the substrate and the resulting digestate. Results indicated significant ($p<0.05$) reduction in nitrogen (82.9%), potassium (54.8%), and magnesium (30.4%) after digestion, while phosphorus and calcium showed more stability with decrease of 24.2% and 3.1%, respectively. The study concludes that co-digestion of poultry manure is an effective method for producing nutrient-rich biofertilizer, though supplementation may be necessary to address specific nutrient deficiencies.
Keywords: Poultry Manure, Anaerobic Digestion, Anaerobic Co-Digestion, Biofertilizer

INTRODUCTION

The increasing global demand for sustainable agricultural practices has led to a growing interest in the use of biofertilizers derived from organic waste materials. Anaerobic digestion, a microbial process that breaks down organic matter in the absence of oxygen, is widely recognized for its potential to convert animal waste into nutrient-rich biofertilizers while simultaneously producing biogas, a renewable energy source (Möller & Müller, 2012). Among various organic wastes, poultry dropping is particularly valued for its high nutrient content, making it an excellent candidate for biofertilizer production (Ravindran *et al.,* 2020).

Poultry dropping is an excellent source of essential nutrients required for plant growth. Layers and broilers, which are integral to the poultry industry, produce significant quantities of dropping with varying nutrient profiles. Layer dropping is typically rich in calcium due to the dietary requirements for egg production, while broiler dropping is often higher in nitrogen and phosphorus, reflecting their rapid growth and protein-rich diets (Kelleher *et al.,* 2002). By co-digesting these two types of dropping, it is possible to balance the nutrient composition of the digestate, potentially enhancing its value as a biofertilizer (Holm-Nielsen *et al.,* 2009).Digestate is the solid and liquid material produced during anaerobic digestion, a process in which microorganisms break down organic matter in the absence of oxygen (Astals *et al*., 2014; Weiland *et al.,* 2019). It is a nutrient-rich byproduct that can be used as fertilizer, soil amendment, or further processed into various products (Li *et al.,* 2020). Digestate is composed of a liquid fraction, known as digestate liquor, and a solid fraction, known as digestate cake (Khanal *et al.,* 2019). The use of digestate as fertilizer has gained attention due to its potential to replace synthetic fertilizers, reducing environmental pollution and promoting sustainable agriculture (Tampio *et al.,* 2019).Substrate is the organic matter that is converted into biogas and digestate during anaerobic digestion, it is also the molecule upon which an enzyme acts to form product (Berg *et al.,* 2015).

Layer and broiler bird droppings offer distinct nutrient profiles, making their co-digestion an attractive strategy. Layer bird droppings are rich in N and P, while broiler bird droppings contain significant amounts of K, Ca, and Mg (Bayer *et al.,* 2018). The combination of these droppings in a 30:70 ratio optimizes nutrient diversity and availability. Anaerobic co-digestion enhances nutrient release and bioavailability, making the digestate and the substrate valuable fertilizer resource (Zhang *et al.,* 2020). N, P, K, Ca, and Mg are crucial macronutrients for plant growth and development (Marschner, 2012). In the current study, their presence in the digestate was evaluated using standardized methods, such as spectrophotometry and atomic absorption spectroscopy (APHA, 2017).

MATERIALS AND METHODS

Experimental site

The study was carried out at the Teaching and Research Farm located at the Naraguta Campus, Jos North, Department of Animal Production., Faculty of Agriculture, University of Jos, Jos Plateau State. The district's yearly temperature is 28.41^{0}C (83.14^{0}F) and it is -1.05% lower than Nigeria's average. Jos North typically receives about 155.51mm (6.12 inches) of precipitation and has 181.54 rainy days (49.74% of the time) annually (https://weatherandclimate.com/amp/nigeria/plateau/jos).

Biomass Collection

Both layer and broiler birds' droppings were collected from the pens of the Teaching and Research Farm, Faculty of Agriculture, University of Jos. They were sun-dried, sieved to remove feed materials and stored in new clean sacks. New and sterile sacks were used to prevent contamination.

Design and Development of Biodigester

Eighty litres bio-digester was designed at the Faculty of Engineering, Department of Civil Engineering, University of Jos and fabricated at *Dilimi* Fabrication Market, Jos North, Plateau State. The digester was fabricated with galvanized iron sheet (this is because of its high resistance to corrosion).

Slurry Preparation

A slurry which was a combination of biomass (manure) and water was prepared. One part of the slurry was biomass while the other was water in a 1:1 combination. The one part of the biomass was a combination of both layer and broiler (30% and 70%) already dried droppings. A 20-litre bucket was used for the slurry preparation; 3 litres of layers and 7 litres of broilers droppings were measured and poured into the bucket after which 10 litres of water was also measured and poured into the same bucket making a total of 20 litres. A wooden spatula was used to mix the combination to get an even mixture.

Sample Collection

The prepared slurry was loaded into the 80-litre bio-digester through the inlet pipe with the aid of a funnel. Fresh cow dung of 1.6 litres was added into the digester to act as inoculum to seed the digester and kickstart the process of anaerobic co-digestion. The biodigester was kept under direct sunlight; this was done to enhance bacterial activity as warm temperatures from sunlight exposure can increase the metabolic rate of the bacteria in the biodigester and accelerates to a higher rate of organic matter breakdown. The experiment was observed for 30 days. The slurry samples were collected into the sample collection bottles. The bottles were sterilized with hot water; both inside and outside were sterilized to kill any pathogenic organisms that can cause contaminations to the samples. The substrate and the digestate were collected into the sterilized bottles and taken to the microbiology laboratory for analysis.

Samples of the slurry, both the digestate and substrate were taken to the laboratory for analysis to check the amount of Nitrogen, Potassium, Phosporus, Magnesium and Calcium in both the digestate and substrate and the results are presented in Table 1 below. The Laboratory analysis was carried out at Optima Kings Research Center and Laboratories located at No.4 Miango Road, Kuffang, Jos, Plateau State, Nigeria.

Methods for Mineral Analyses

Determination of Phosphorus Content

Phosphorus in the samples were determined according to Onwuka (2005) by molybdate method using hydroquinone as a reducing agent. A mixture of 1.0 ml ammonium molybdate, 1.0 ml sodium sulphate, 1.0 ml hydroquinone and 0.5 ml of the mineral digest was agitated and allowed to stand for 30 minutes. The blue colour developed was quantified using a colourimeter at 660 nm against a standard.

Determination of Calcium Content

The calcium content was determined by titration method according to Pearson (1991) procedure. About 10 ml of each of the samples were pipetted into a 250 ml conical flask and 25 ml of KOH with a pinch of calcine indicator was added. The mixture was titrated against EDTA (ethylene diamine tetra acetate) solution to get an end point. The volume of EDTA is the equivalent volume of calcium in the sample.

Determination of Potassium Content

Determination of potassium in the samples was done using A.OA.C. Method 958.02 (Potassium in Fertilizers). The samples were digested with ammonium oxalate, (NH4)2C2O4 and hdyrogen peroxide, H_2O_2. The samples were titrated with BAC solution (benzylalkonium chloride) using a sodium tetraphneylboron (STPB) indicator to measure the potassium.

Determination of Magnesium Content

the magnesium content was determined according to the method of AOAC 964.01D 1 g of the sample was weighed into 500mL volumetric flask, 350mL of water was added and boiled for an hour (1h). It was allowed to cool, diluted to volume, mixed, and filtered. Aliquot portions of the solution prepared were transferred into a beaker and the Mg determined using KOH to adjust pH.

Determination of Nitrogen Content

The total Nitrogen content was calculated using the relationship that 1 ml of H_2SO_4 = 14 mg of H2SO4 thus. Where;

T = Titre value of the sample
B = Blank titre value
Ca = Volume of digest distilled
Vt = Total volume of digest
N = Normality of acid used
W = Weight of sample used

Statistical/Data Analysis

Analysis was carried out using independent t-test at 0.05 level of significance to test for the effect of anaerobic co-digestion process on biofertilizer quality of laying and broiler birds' droppings. The SAS ODA (On Demand for Academics) Version 3.81 was employed in the analysis.

RESULTS AND DISCUSSION

Table 1 above shows the mineral analysis of digested and undigested laying bird and broiler droppings, with the t-value indicating significant ($p<0.05$) differences between the mineral content of the digested and undigested samples for Nitrogen and Potassium, while Phosphorus, Magnesium and Calcium showed no statistical ($p>0.05$) difference. The SD values represent the spread of individual mineral content values within each group (digested and undigested), and the SE values represent the variability of the sample mean for each mineral content group. For Nitrogen, the undigested sample had a mean of 0.251% while the digested sample had a mean of 0.043%. This is consistent with the work of Brown *et al.* (2018), who reported up to 80% reduction during anaerobic digestion due to the conversion of organic nitrogen into gaseous forms. For Phosphorus, the undigested sample had a mean of 0.330% while the digested sample had a mean of 0.250%, showing a non-significant reduction ($p > 0.05$), aligning with the work of Taylor *et al.* (2016), who attributed this stability to phosphorus's inorganic nature. For Potassium, the undigested sample had a mean of 0.840% while the digested sample had a mean of 0.380%, with a significant reduction, similar to the findings of White & and Johnson (2019) who noted potassium's leaching due to its high solubility. For Magnesium, the undigested sample had a mean of 0.230% while the digested sample had a mean of 0.160%, with a non-significant reduction ($p > 0.05$), which is consistent with the report of Harris & and Lee (2020), who noted its stability or precipitation as struvite. For Calcium, the undigested sample had a mean of 2.890% while the digested sample had a mean of 2.800%, showing a slight non-significant decrease ($p > 0.05$), in line with the submission of Williams *et al.* (2020), who observed calcium's stability during digestion.

Table 1: Effect of Anaerobic Co-Digestion Process on Biofertilizer Quality of Laying Birds and Broiler Droppings

Mineral	Category	Mean (%)	SD	SE	t-value	Prob>t
Nitrogen	Undigested	0.251	0.003	0.002	73.54	0.0002
	Digested	0.043	0.003	0.002		
Phosphorus	Undigested	0.330	0.028	0.020	2.83	0.1056
	Digested	0.250	0.028	0.020		
Potassium	Undigested	0.840	0.028	0.020	16.26	0.0038
	Digested	0.380	0.028	0.020		
Magnesium	Undigested	0.230	0.028	0.020	2.47	0.1318
	Digested	0.160	0.028	0.020		
Calcium	Undigested	2.890	0.028	0.020	0.45	0.6981
	Digested	2.800	0.283	0.200		

Key: SD: standard deviation, SE: Standard error.

CONCLUSION

This study revealed significant reduction in nitrogen and potassium content after digestion, while phosphorus, magnesium, and calcium show non-significant changes. These results align with findings from other studies, confirming the trends observed in nutrient dynamics during anaerobic digestion. The data suggests that while some nutrients are significantly reduced during the process, others remain relatively stable, providing valuable insights for optimizing the production and application of biofertilizers. Anaerobic co-digestion significantly impacted the nutrient composition of the substrate, particularly reducing nitrogen, potassium, and magnesium levels, phosphorus and calcium remain more stable. These findings are consistent with recent research, highlighting the need for nutrient management strategies to maintain the fertilizer value of digestates.

REFERENCES

American Public Health Association (APHA) (2017). Standard methods for the examination of water and wastewater (23rd ed.). *American Public Health Association*.

Astals, S., Nolla-Ardèvol, V., & Mata-Alvarez, J. (2014). "Anaerobic co-digestion of pig dropping and crude glycerol at mesophilic conditions: Biogas and digestate." *Bioresource Technology*, 169, 198-205.

Bayer, C. A., Kraft, E. E., Wichmann, H. J., & Müller, H. B. (2018). Anaerobic digestion of broiler litter: Effects of co-digestion with cattle dropping on methane production and digestate quality. *Waste Management,* 76, 447-455.

Berg, J. M., Tymoczko, J. L., Stryer, L., Gatto, G. J., & Gregg, A. (2015). *Biochemistry. New York: W. H. Freeman and Company.*

Brown, L., Smith, K., & Lee, C. (2018). Phosphorus Dynamics in Anaerobic Digestion. *Waste Treatment Journal*, 29(4), 435-443.

Harris, P., & Lee, A. (2020). Calcium Dynamics in Anaerobic Digestion Residues. *Waste Management Research*, 38(6), 789-797.

Holm-Nielsen, J. B., Al Seadi, T., & Oleskowicz-Popiel, P. (2009). "The future of anaerobic digestion and biogas utilization." *Bioresource Technology*, 100(22), 5478-5484.

https://weatherandclimate.com/amp/nigeria/plateau/jos

Kelleher, B. P., Leahy, J. J., Henihan, A. M., O'Dwyer, T. F., Sutton, D., & Leahy, M. J. (2002). "Advances in poultry litter disposal technology – a review." *Bioresource Technology*, 83(1), 27-36.

Khanal, S. K., Rasmussen, M. L., & Shrestha, P. (2019). Anaerobic digestion processes: Applications and advancements. *Water Research,* 151, 381-392.

Li, A. M., Chen, X., & Zhang, J. (2020). Digestate: *A valuable resource for agriculture and energy production. Sustainability,* 12(11), 4567.

Marschner, H. (2012). Marschner's *Mineral Nutrition of Higher Plants, Third Edition. Academic Press*.

Möller, K., & Müller, T. (2012). "Effects of anaerobic digestion on digestate nutrient availability and crop growth: *A review." Engineering in Life Sciences,* 12(3), 242-257.

Onwuka, G. I. (2005). Food Analysis and Instrumentation: Theory and Practice. Naphthali Prints, Lagos, Nigeria 1st edition. 123-124,133.

Pearson's Composition and Analysis of Foods, 9thedn (1991) – Modified Mohr method.

Ravindran, B., Nguyen, D. D., Chaudhary, D. K., Chang, S. W., Kim, J., & Lee, S. R. (2020). "Potential valorization of food waste digestate towards value-added bio-products: A review." *Science of The Total Environment*, 748, 141312.

Tampio, E. M., Salo, T. T., Rintala, J. A., Heinonen, T. T., & Kallio, M. T. (2019). Nutrient recovery from dairy farm waste using anaerobic digestion and chemical precipitation. *Journal of Cleaner Production,* 235, 1220-1228.

Weiland, M. P., Rozzi, A., & Fazi, S. (2019). Anaerobic digestion: A multi-disciplinary review. *Environmental Science & Technology,* 53(12), 7111-7123.

White, J., & Johnson, M. (2019). Magnesium Precipitation During Anaerobic Digestion. *Environmental Science & Technology*, 53(11), 6625-6632.

Williams, A., & Martin, S. (2020). Calcium Content in Poultry Dropping. *Agricultural Nutrient Studies*, 31(3), 274-281.

Zhang, Y. Y., Wang, X. C., Li, X. H., Li, Q. B., & Chen, X. X. (2020). "Enhanced biogas production from anaerobic co-digestion of layer and broiler dropping with crop waste". *Environmental Science and Technology,* 54(19), 11456-11464.