Prospect of Recovering Bio-fertilizer by Anaerobic Co-digesting Cow Manure, Palm Oil Sludge, and Cassava Peels

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Abstract:
Improper crop and animal waste management and disposal are now widely recognized as environmentally harmful practices. When crop waste is placed in landfills, greenhouse gases (GHG) like carbon dioxide (CO_2) and methane (CH_4) are created. In order to create the digestate for usage as bio-fertilizer from agricultural waste employing cow dung as an inoculum for 30 days of the hydraulic retention period, a 225L Polyethylene (PE) anaerobic digester was used in this study. Cassava peels, palm oil sludge, cow dung, and water were mixed in a 1:1:2:5.3 ratio. About 1.3 kilogram of crushed eggshells was added to keep the pH level within the range recommended for the anaerobic digestion process. In order to maintain mesophilic conditions during anaerobic co-digestion for enhanced organic fertilizer output, the greenhouse was used to regulate temperature. Since microbial populations flourish in friendly environments, the pH averaged 6.0 and the average slurry temperature was 34.76 ^oC during digestion. After 30 days of hydraulic retention time, a laboratory-scale elemental analysis of the digestate showed that the contents of nitrogen (N), phosphorus (P), and potassium (K) increased by 95%, 75%, and 93.8%, respectively. The anaerobic co-digestion of animal and agricultural waste has created digestate rich in NPK nutrients, but more research should be conducted to see whether the biofertilizer's efficacy on fast-growing crops can be determined by measuring the number of harvests and height of the plants.

Keywords: Agricultural waste; Anaerobic digestion; Bio-fertilizer; Co-digestion; Digestate; Environmental sustainability; Greenhouse gases.

1. Introduction

The term "digestate" refers to the leftovers of the materials used as feedstocks for the anaerobic digestion (AD) process, which is used to treat trash for biogas production. The kind and makeup of the organic wastes used as substrates for anaerobic digestion, as well as the level of total solids (TS) present inside the anaerobic biodigester, work together to define the quality of the digestate [1]. Digestates can be used as a bio-fertilizer to improve soil quality, according to numerous research studies, because they contain potential nutrients including nitrogen (N), phosphorus (P), and potassium (K), as well as other substances like vitamins, nucleic acids, calcium, etc. [2,3]. The quality of the digestate is improved when there are more biosolids present, making it better to use as fertilizer [1]. When the anaerobic digester's metabolic activity is slow, it tends to limit how much phosphorus and nitrogen can be removed from the organic wastes utilized as feedstocks [4]. When total nitrogen is converted to ammonium (NH_4^+) and total phosphorus is converted to PO_4^{3-} as chemical active forms, the quality of the digestate to be used for improving soil components and agricultural farming is also improved [5]. However, using this certified digestate as bio-fertilizer has several advantages over using organic waste that has not been digested including higher concentrations of NPK nutrients, decrease of pathogens and helping to protect the environment and public health [6].

Crop wastes (CW) cause environmental pollution, hence proper handling and treatment of them has become a global trend in many countries [7]. According to a study by [8], large amounts of greenhouse gases (GHGs), such as carbon dioxide (CO_2) and methane (CH_4), are released when agricultural waste is dumped in landfills. The release of GHGs into the atmosphere, where CH_4 is more destructive than CO_2, is thought to be the primary contributor to global warming [9]. Although effective management of cow dung (CD) has not yet been developed, it has either been used as a heating source after sun drying or as untreated soil fertilizer, ignoring the potential effects on groundwater or soil contamination [10]. Because they contain a variety of nutrients, including the nitrogen that methanogens need, as well as a high buffering capacity, cow dung and other livestock manures are considered potential co-substrates [11]. The faeces that animals produce can be blended with grasses that are used as bedding materials in livestock manure [12]. Animals have different digestive systems, so the composition of feedstocks for the AD process that uses animal excrement may vary from one another [13]. Cow manure is an example of an alkaline manure that contains nutrients such as calcium, magnesium, sulphur, potassium, phosphorus, and nitrogen. As a result, it has a lower carbon to nitrogen ratio than crop wastes [14,15].

Anaerobic digestion (AD) uses anaerobic bacteria and several biological reactions which result in the production of methane (CH_4), carbon dioxide (CO_2), and other byproducts from stable organic matter [16]. While anaerobic digestion can produce biogas from the volatile solids (VS) from 40% to 60% of organic wastes from foods, proper disposal of the remaining solids in some amounts is required [17]. Currently, when pursuing Sustainable Development Goals (SDGs), the production of bio-fertilizer from AD of biowaste has been regarded to alleviate hunger and promote sustainable communities [18]. In addition, AD is effectively utilized to treat organic waste, which reduces waste buildup and increases the number of nutrients available to plants through digestates [19]. The ability of anaerobic digestion can be enhanced by co-digesting more than one type of organic waste, such as animal manure and crop straw, to reduce solid residues below 40% [20]. Anaerobic digesters frequently use a variety of energy crops, organic fraction of municipal trash, food waste, and animal manure as substrates [21]. The features of the substrates' biodegradability may have an impact on the AD process, altering the quality of the digestate [22]. Anaerobic digestion (AD) is known as a multi-step biochemical process that has four sequential steps namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis [17]. According to [23], microorganisms are responsible for converting waste from food like crop waste (CW) into intermediate metabolites that methanogens can utilize later.

Anaerobic co-digestion has recently attracted a lot of attention as a potential remedy for issues related to the mono digestion of waste from foods [24]. As a result of anaerobic co-digestion, the digestion process within the reactor becomes stable, boosting the biogas output because of the mixed feedstocks' varied composition, which results in a balanced C:N ratio, pH, and presence of crucial trace elements [21]. The maximum permitted organic loading rate (OLR) for anaerobic co-digestion might be increased to 10 kg VS per m^3 per day by using cow dung as a co-substrate since it includes a variety of nutrients and has a significant buffering capacity [25]. The advantages of anaerobic co-digestion include providing an equilibrium of nutrients, increasing buffering capacity, decreasing ammonia inhibition, dilution of toxicity and producing nutrient-rich digestate that can be used as fertilizer [26,27]. According to [28], after the anaerobic co-digestion of activated sludge and food waste, several heavy metals (As, Cd, Hg, Pb, and Cr) were discovered in the distillate and they were determined to be more than the Chinese national standard for fertilizer.

The optimal environment for digestion is provided by anaerobic co-digestion, which addresses a variety of practical difficulties including pH and temperature control, substrate biodegradability, and moisture content (MC) [25,29]. Additional important elements for the advantageous effects of anaerobic co-digestion include the ratios of CW and CD to be mixed, the make-up of the feedstocks to be combined, and the presence of low inert organic matter [10]. Therefore, to recover bio-fertilizer for soil applications, this study was carried out considering the ongoing quest for knowledge and the available data on the quality of digestate from anaerobic co-digestion of palm oil sludge, cassava peels, and cow manure.

2. Materials and Methods

a. *Feedstocks*

Cassava peels from the cassava crop and palm oil sludge collected during the pressing of palm tree fruits to produce palm oil are agricultural wastes employed. In this study, the inoculum was cow dung from an abattoir in Ota, Ogun State, Nigeria. Cassava peels were gathered from Owode in Ogun State, while palm oil sludge came from a mill at Covenant University in Canaanland, Ogun State, Nigeria.

b. *Mixing ratio*

In a weight-based ratio of 1:1, 15 kilograms of cassava peels and 15 kilograms of palm oil sludge were well mixed. In a weight-based ratio of 1:2, 30 kilograms of cow dung was introduced to the substrate mixture as an inoculum. Eighty (80) liters of fresh water were then added to the substrate and inoculum mixture. As a result, the proportions of palm oil sludge, cassava peels, cow dung and water were formed in the optimal ratio of 1:1:2:5.3.

c. *Physiochemical parameters' measurement*

The physiochemical parameters including carbohydrates, proteins, lipids, total solids (TS), volatile solids (VS), total carbon (TC), total nitrogen (TN), total phosphorus (TP), total potassium (TK), volatile fatty acids (VFAs), and moisture content of sludge before and after digestion were measured using standard methods as presented in Table 1. The pH of the slurry was measured daily using a pH meter after adding 1.3 kilogram of ground eggshells to the substrate mixture. The 225L PE anaerobic biodigester was raised in a greenhouse made of transparent plastic sheet to preserve this interior temperature at about 34.76°C which is between 30°C and 45°C of the mesophilic range.

3. Results and Discussion

a. *Physicochemical properties of feedstocks*

The undigested slurry and digested slurry were utilized to determine the physicochemical properties of the combined mixture of substrates and inoculum employed for this experiment. The average reduction of the three macronutrients to 45% is the consequence of hydrolysis, which reduced the quantity of the three macronutrients: carbohydrates, proteins, and lipids into smaller, more soluble molecules known as monomers. The results of the laboratory tests conducted at a temperature of 25 °C and a humidity of 51% are shown in Table 1. These results show the amount of tested parameters that was in the sludge both before and after the anaerobic digestion process. Prior to digestion, the sludge had more carbohydrates than protein or fat, which made it easier for anaerobic bacteria to break down the material [25]. The concentration of total solids (TS) was reduced by 25% after 30 days of anaerobic sludge retention. The reactor's dry digestion phase was made possible by the percentage reduction in total solids to 14.25% because of their capacity to extract volatile solids (VS), which minimizes the cost of pre-treating and dewatering digestate [30].

Table 1: Pre-digestive and digestive physicochemical properties of feedstocks

S/N	Test Parameter	Result Found		Uncertainty (Uc)	Level of detection (LoD)	Test Method
		Before digestion	After digestion			
1.	Protein content (mg/L)	227.00	102.00	N/A	0.01	AOAC 930.25
2.	Fat content (mg/L)	364.00	164.00	0.13	0.01	AOAC 922.06
3.	Carbohydrate (mg/L)	527.00	237.00			
4.	Dietary fiber (mg/L)	217.00	87.00	0.3	0.01	AOAC 945.10
5.	Total ash content (mg/L)	210.00	84.00	0	0.01	AOAC 923.03
6.	Moisture content (%)	79.29	71.36	0.0009	0.0001	AOAC 925.10
7.	Free fatty acid (mg/L)	525.00	210.00	0.12	0.001	IS 548:2010
8.	Total solids (%)	56.93	14.25	0.13	0.001	APHA 4500-1
9.	Volatile solids (%)	51.86	12.97	N/A	0.0001	APHA 4500-1
10.	VS/TS (%)	91.09	91.02	N/A	N/A	Calculation
11.	pH	4.00	6.00	N/A	N/A	Multimeter: HI 9813-5

NOTE: Uc= Uncertainty which was calculated according to the value of the standard deviation multiplied by a coverage factor of K= 2 to get a confidence level of 95% approximately, according to the requirements of accreditation standards.

The pH of slurry was changing with changes in ammonia levels and volatile fatty acid (VFA) levels because proteins in substrates undergo degradation [31]. After thirty (30) days of digestion, the volatile fatty acid (VFA) concentration decreased to 12.97%, which aided in pH maintenance and sped up the breakdown process. The carbon to nitrogen (C:N) ratio of the sludge before digestion was 21.53, which is within the range of 20 and 30, and indicates an adequate, ideal mix of substrates for a healthy anaerobic digestion process [12].

b. Quality of the digestate

As seen in Figure 1, the nutritional composition of the digestate, specifically its nitrogen (N), phosphorus (P), and potassium (K) content, was examined in this study to ascertain its quality. The concentration of nitrogen (N), phosphorus (P), and potassium (K) increased by 95%, 75%, and 93.8%, respectively, according to a laboratory-scale elemental analysis of the digested sludge performed after 30 days of hydraulic retention time. By using ground eggshells to stabilize the pH and a greenhouse to regulate the temperature, anaerobic co-digestion was able to continue in a conducive environment for slow metabolic reactions. This rise in the digestate's nutrient makeup is more evidence of this success.

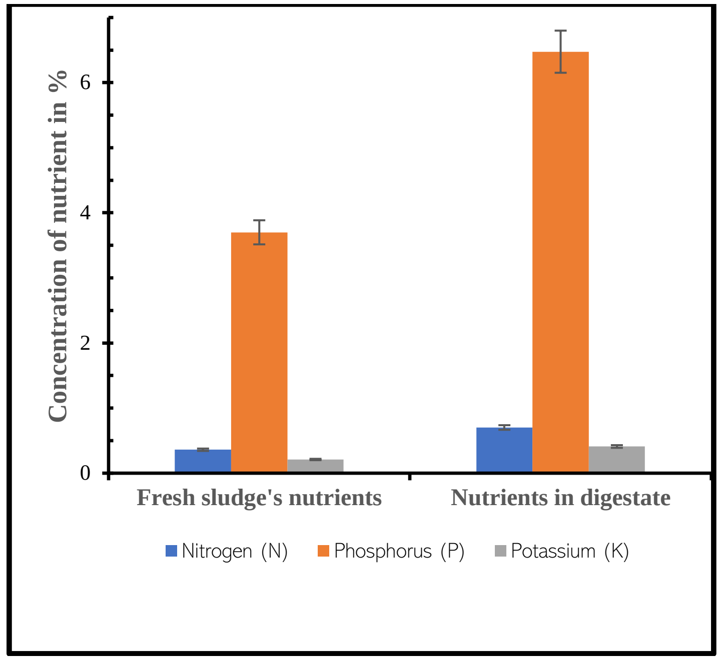

Figure 1: Concentration of nutrients in fresh sludge and digestate

The final concentration of 0.702% for nitrogen (N), 6.475% for phosphorus (P), and 0.41% for potassium (K) in the digestate was found to be higher than the values obtained in a study conducted by [2], demonstrating that the obtained digestate was enriched with nutrients for use as a high quality biofertilizer for soil amendment and crop production. Even in [32]'s study, where they employed a control plant to grow well using an organic fertilizer they produced in their study with lower phosphate (P) and potassium (K) concentrations than those found in this study, the use of nitrogen-phosphorus-potassium (NPK) biofertilizer was accepted.

4. Conclusion

According to the study's findings, anaerobic co-digestion is a feasible and environmentally responsible way to reduce the amount of waste produced by cow manure, cassava peels, palm oil sludge, and eggshells while still producing digestate that is nutrient rich. The digestate created by the anaerobic co-digestion process contained more nitrogen (N), phosphorus (P), and potassium (K), which are vital minerals for soil improvement and crop growth. An effective method for managing organic waste that can potentially result in the production of organic fertilizer and support a circular economy in developing nations is anaerobic co-digestion of agricultural waste and animal manure. However, another significant determinant of an organic fertilizer's efficacy is how it impacts plant development. The most practical, efficient, cost-effective, and low-tech design for leveraging solid-liquid separation to turn nutrient-rich digestate into biofertilizer should be investigated further. This effort will result in biosolids and effluent that are richer in nutrients, enabling for testing of the program's success, by measuring the height and bulk of the harvest from quickly growing crops like beans.

Declaration of Competing Interest

The authors certify that none of their known financial or personal conflicts appeared to have a bearing on the findings provided in this paper.

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