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PHYSICO-CHEMICAL PROPERTIES OF VARIOUS BIOMASS USED IN ANAEROBIC DIGESTION

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ABSTRACT

The challenge of sufficient sources of energy, the high cost of the available sources, and the emission of greenhouse gases harmful to both man and his surroundings amongst others, Initiate the need for renewable sources of energy that are available and affordable. This study focuses on the physicochemical properties of the substrate and digestate of biomass (fruit waste with sheep dung and food waste with human excreta). The hydraulic retention time was 30 days, within the mesophillic temperature range (30 – 40ºC) using a digester with 25 liter capacity, the biomass used was mechanically pre-treated. The pH of the medium reduced progressively from 7.75 to 7.45 and 7.4 to 7.25 for fruit waste with sheep dung and for food waste with human excreta respectively. This study shows that the synthesis of fruit waste with sheep dung and food waste with human excreta can produce sufficient carbon that will accelerate effective gas generation as an alternative energy source in Nigeria. Additionally, from the values of the physicochemical properties (nitrogen, phosphorus and potassium), the biomass is a good replacement for the conventional chemical fertilizer used on farms which are more expensive to come by.

KEYWORDS: Physicochemical properties, biomass, substrate, disgestate, anaerobic digester

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1. INTRODUCTION

Scarcity of petroleum and other fossil for energy threatens supply of fuel throughout the world, problems caused by of green-house gas emission particularly CO_2 and other harmful gas that deplete the ozone layer and cause global warming Leads to research in different corners to access new and safe sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biodiesels, biobutanol, and biogas are all renewable energy resources. But, biogas is distinct from other renewable form of energy because of its characteristics of collecting, use and control of organic wastes and at the same time producing fertilizer for Agriculture. Biogas does not require advanced technology for producing energy and does not have any geographical limitations, it also is very simple to use and apply.

Physicochemical analysis is very important to get the exact idea about the quality of waste material to be used for biogas production [1]

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions, in a process known as anaerobic digestion [2]. Anaerobic treatment is the use of biological processes, in the absence of oxygen, for the breakdown of organic matter and the stabilization of these materials by conversion to methane and carbon dioxide gases and a nearly stable residue [3].

According to ASABE S593.1 standard[4] biomass consists of organic materials that are plant or animal based, including but not limited to dedicated energy crops, agricultural crops and trees, food and fiber crop residues, aquatic plants, forestry and wood residues, agricultural wastes, bio-based segments of industrial and municipal wastes, processing by-products and other non-fossil organic materials.

The use of biogas is capable of providing a special impetus in both rural and urban areas. Biogas plant can be built by using materials which are locally available in most developing countries [5]. Natural generation of biogas is an important part of bio-geochemical carbon cycle.

Anaerobic digestion is controlled biological degradation process which allows efficient capturing & utilization of biogas (approx. 60% methane and 40% carbon dioxide) for energy generation. Biogas digester systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. The performance of an anaerobic co-digestion system is tied closely to the structure of its microbial community [6].

Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. [7]Pritchard 2009 et al found that numerous health problems have been reported to be associated with spread of human and animal waste. Human waste can leach into ground water from a functioning pit toilet, contamination of groundwater and reservoirs by running storm water and flash floods can result in significant sporadic pollution events, and the type of contamination includes enterobacteria, enteroviruses and a range of fungal spores. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse (residuals). The anaerobic digestion of waste can have positive environmental value since it can combine waste removal and stabilization with net fuel (Biogas) production. The solid or liquid residue can further be used as feed, as biomass briquette for cooking [5] or as a fertilizer.

The objective of this research is to carry out the physicochemical analysis of the substrate and digestate of human excreta and waste gotten from Landmark University Cafeteria for biogas production.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this research are; pineapple waste, plantain peel, kitchen waste, fresh cattle dung, and human excreta which was sourced from the Landmark University Teaching and Research Farm and the Landmark University Cafeteria Omu-Aran (Latitude: 8.14^0N, Longitude: 5.09^0E), Kwara State, Nigeria.

2.2. Equipment and Devices

The equipment and devices used in this research study are hammer mill, pH meter (Hanna instruments pH/^{o}C Bench meter), water bath, mercury-in-glass thermometer, weighing scale (Poyear platform weighing scale), locally fabricated anaerobic digester (Painted black for absorbing heat energy), water displacement system, gas holder/cylinder with burner (TL Lpg Gas Bottles), rubber hose, nose cover, buckets, hand gloves, funnel, U Clear Heating Drying Oven (DHG-9053A), photometer (ELE internationals).

2.3. Apparatus

Within the scope of this research work the type of reactor used was the discontinuous reactor (batch reactor)

Batch reactor or digester**:** The mesophilic batch experiments were performed in 25-liter digester. The reactors had a frustum shape. The biogas generated in the reactor was collected in a gas cylinder via a tube attached to the gas sampling port. As shown in plate 1.0.

2.4. Experimental Device Design and Setup

Two 25 liters capacity anaerobic digesters were fabricated at a metal fabricating workshop in Omu-Aran Kwara state. It was made of galvanized plate in the form of a cylinder for better mixing of the substrate and painted with black plaint in order for it to absorb heat energy from the sun during the day and provide supplemental heat during the night. The digester with dimensions 50 cm height and 25 cm diameter had a handle with a stirrer fixed on top of the digester. The digester had three openings on top of it which were for feed inlet, thermometer holder and the gas outlet. The digester had a tap fixed towards its bottom side for the collection of samples and slurry outlet. Rubber hose was used to connect the digester to the gas collection system and then to the gas cylinder burner for storage until it was used as cooking gas in the cooking test. The gas produced in the digester cylinder was collected in the gas collection cylinder with water jacket having dimensions 25 cm high and 17 cm diameter working on the principle of water displacement for easy measurement of the volume of gas produced per day, this displacement is dependent on the pressure and volume of gas produced. The gas collected in the water jacket set-up is passed through to the gas cylinder for storage.

Plate 1 Experimental setup of the anaerobic digester

2.5. Physicochemical Analysis of the Substrate, Digestate and Biogas

The analysis of the physicochemical properties of the substrate and digestate of the co-digestion of plantain plant residues and cattle dung, cashew waste and cattle dung were carried out. The substrate samples were collected before it was loaded into the digester, the physicochemical properties that were analyzed are: ammonia nitrogen, total phosphate, total alkalinity, pH, aluminum, potassium, iron, total copper, magnesium, calcium, zinc, DO (dissolved oxygen), total nitrogen, organic carbon, total kjedahl nitrogen, ash content, phosphorous, conductivity, volatile solids, and total solids. The ELE International Paqualab Photometer analyzed the physicochemical properties such as: ammonia nitrogen, total phosphate, total alkalinity, pH, aluminum, potassium, iron, total copper, magnesium, calcium, zinc, COD (chemical oxygen demand), DO (dissolved oxygen), total nitrogen, while the analysis on organic carbon, total kjedahl nitrogen, ash content, conductivity and phosphorous test were done using Walkley-black titration method, Kjeltex auto-distillation apparatus model, Muffle furnace, Electrochemical analyser (Consort C6020) respectively, while volatile solids content were calculated from the value of the ash content of the samples. For the total solids content of the substrates, 10 g of the collected samples were weighed each in a beaker using the weighing scale and they were analyzed in an oven (U Clear model DHG-9053A) at 150^0C for 1 hour 30 minutes. The dried samples were then crushed with a porcelain mortar and pestle to powder; the powder was weighed after which the total solids content of the samples were then calculated. For the parameters analyzed with the ELE International Paqualab Photometer at the

Environmental Engineering laboratory, a plastic syringe was used to take the samples from the sample containers to the sample holder where 100 ml of water was added to the sample and it was agitated continuously for homogenous mixing, then the sample holder was inserted in the photometer where the parameters where analyzed. 200 ml of the collected samples were weighed each in a beaker using the weighing scale and they were analyzed in an oven (U Clear model DHG-9053A) at 180^0C for 3 hours 30 minutes. The dried samples were then crushed with a porcelain mortar and pestle to powder where they were analyzed at the Animal Science laboratory for analysis of the organic carbon, total kjedahl nitrogen, ash content, conductivity and phosphorous test. After the completion of the 30 days retention period, the digestate samples were collected to analyze the physicochemical properties as represented in Table 1.0 and 1.1

3. RESULTS AND DISCUSSION

3.1. Physicochemical Properties of Substrate and Digestate

The physicochemical properties of the digester feedstock before and after the anaerobic digestion are shown in Table 1, 2, 3 and 4 fruit waste with sheep dung, food waste with human excreta, Tithonia diversifolia with cow dung and kitchen waste with poultry droppings .respectively. The values obtained ash content, organic carbon, total kjedahl nitrogen, pH showed an increase after the anaerobic digestion while other parameters such as total solids, volatile solids, aluminum, copper, iron, calcium and ammonia nitrogen decreased in values after the digestion process. This observation is in line with what was earlier reported by [8]. However, the value of nitrogen, phosphorus and potassium in the digestate indicates that it will be good for fertilizer application for agricultural products. The Carbon/Nitrogen ratio of the feedstock was approximately 4:1.

Table 1 Physicochemical properties of substrate and digestate for fruit waste and sheep dung

Properties	Substrate	Digestate
pH	7.75	7.45
Ammonia Nitrogen (mg/L N)	0.4	0.24
Total phosphate (mg/L P)	3.71	2.41
Total Alkalinity (mg/L $CaCO_3$)	350	250
Aluminum (mg/L Al)	0.35	0.28
Potassium (mg/L K)	4.4	3.6
Iron/10 (mg/L Fe)	5.20	3.5
Copper total/5 (mg/L Cu)	2.90	1.8
Magnesium (mg/L Mg)	75	34
Calcium (mg/L Ca)	22.0	76
Zinc/35 TT (mg/L Zn)	24.0	13.5
DO (dissolved oxygen mg/L O_2)	2.4	1.02
Total nitrogen TT/30 (mg/L N)	24.0	1.58

Table 2 Physicochemical properties of substrate and digestate for human excreta with kitchen waste

Properties	Substrate	Digestate
pH	7.40	7.25
Ammonia Nitrogen (mg/L N)	0.27	0.16
Total phosphate (mg/L P)	2.49	1.83
Total Alkalinity (mg/L $CaCO_3$)	245	205
Aluminum (mg/L Al)	0.29	0.18
Potassium (mg/L K)	3.70	3.3
Iron/10 (mg/L Fe)	3.50	2.75
Copper total/5 (mg/L Cu)	1.95	1.40
Magnesium (mg/L Mg)	38	26
Calcium (mg/L Ca)	62	170
Zinc/35 TT (mg/L Zn)	14.5	10.0
DO (dissolved oxygen mg/L N)	3.7	0.78
Total nitrogen TT/30 (mg/L N)	20	1.18

Table 3 Physiochemical properties of substrate and digestate for Tithonia diversifolia and cow dung.

Physiochemical Properties	Substrate	Digestate
pH	8.45	7.35
Ammonia Nitrogen (mg/L N)	0.45	0.21
Total phosphate (mg/L P)	5.15	2.16
Total alkalinity (mg/L $CaCO_3$)	380	225
Aluminum (mg/L Al)	0.26	0.25
Potassium (mg/L K)	5.40	3.40
Iron/10 (mg/L Fe)	3.60	3.10
Copper total/ 5 (mg/L Cu)	1.90	1.65
Magnesium (mg/L Mg)	55	29
Calcium (mg/L Ca)	2.0	110
Zinc/35TT (mg/L Zn)	14.0	12.5
Total Nitrogen TT/30 (mg/L N)	1.52	1.36
DO (dissolved oxygen mg/L O_2)	1.8	1.00

Table 4 Physiochemical properties of substrate and digestate for kitchen waste and poultry droppings.

Physiochemical Properties	Substrate	Digestate
Ph	7.55	7.50
Ammonia Nitrogen (mg/L N)	0.26	0.39
Total phosphate (mg/L P)	2.62	2.83
Total alkalinity (mg/L $CaCO_3$)	350	350
Aluminum (mg/L Al)	0.41	0.38
Potassium (mg/L K)	3.90	4.00
Iron/10 (mg/L Fe)	4.00	3.90
Copper total/ 5 (mg/L Cu)	2.25	2.75
Magnesium (mg/L Mg)	75	65
Calcium (mg/L Ca)	18	44
Zinc/35TT (mg/L Zn)	15.5	16.5
Total Nitrogen TT/30 (mg/L N)	1.96	1.82
DO (dissolved oxygen mg/L O_2)	1.26	1.78

3.2. Discussion

The pH of the mono-digestion of cattle dung before digestion was 7.12 and after digestion was 6.98, that is a percentage decrease of 1.97%, this showed a gradual reduction in the pH level [9]. The co-digestion Tithonia diversifolia with cow dung carried out in this research showed a remarkable decrease in the pH level after digestion, which is from 8.45-7.35, which is a percentage decrease of 13%. The pH level gotten proves that co-digestion of *Tithonia diversifolia* with cow dung is more ideal to use in the production of bio-fertilizer as compared with the mono-digestion of cattle dung since the pH level after digestion is slightly alkanaic as opposing the mono-digestion which is acidic.

4. CONCLUSION

The following conclusions were drawn from investigating the physicochemical properties of the digester feedstock before and after the anaerobic digestion. The temperature of the digestate remained constant at mesophilic range (30 - 40ºC) throughout the fermentation period. Hence, temperature does not have any significant effect on the amount of gas produced daily as revealed in this study. The pH of the medium changes progressively from acidic to slightly alkaline. This could be attributed to the nature of the feed within the digester.

The ash content, organic carbon, total nitrogen, pH increased after the anaerobic digestion while the total solids, volatile solids, aluminum, copper, iron, calcium and ammonia nitrogen decreased in values after the digestion process. The C/N ratio of the feedstock was approximately 4:1. The lower rate obtained indicated a faster rate of decomposition which corresponds to the biodegradability of the substrate during digestion.

Additionally, from the values of the physicochemical properties (nitrogen, phosphorus and potassium), the biomass is a good replacement for the conventional chemical fertilizer used on farms which are more expensive to come by.

REFERENCES

[1] Shweta Choubey, Arvind Kumar Swarnakar, Rakesh Kumar Sharma. (2016). Analysis of Physicochemical parameters for Water Quality: A review. Proceedings of the Conference: Bitcon, At Durg, Chhattisgarh, India, (15-16)

[2] Garba, B. and Atiku, S. (1992). Effect of some operating parameters on Biogas production rate. *Nigeria Journal of Renewable energy* 6 (3): 343-344.

[3] Cassidy, D.P., Hirl, P.J., and Belia, E. (2008). Methane production for ethanol coproduction in anaerobic SBRS. *Water and Science Technology,* 58 (4): 789-793

[4] ASABE (2011). Terminology and definition for biomass production, harvesting and collection, storage, processing, conversion and utilization. *ANSI/ASABE* S593.1. January 2011. pp 821-824.

[5] Baki, A.S. (2004). Isolation and identification of microbes associated with biogas production at different retention time using cow dung. M.Sc unpublished dissertation, Sokoto: Usmanu Danfodiyo University.

[6] Stroot, P.G., McMahon, K.D., Mackie, R.I., and Raskin, L. (2001): Anaerobic codigestion of municipal solid waste and biosolids under various mixing conditions: I. Digester performance. Water Research, 35(7), 1804-1816

[7] Pritchard, M., Mkandawire, T., Edmondson, A., O‟Neill, J.G., and Kululanga, G. (2009). Potential of using plant extracts for purification of Shallow well water in Malawi. Phys. Chem. Earth.; 34:799-805.

[8] Owamah HI, Dahunsi SO, Oranusi US, Alfa MI (2014) Fertilizer and sanitary quality of digestate biofertilizer from the co-digestion of food waste and human excreta. J Waste Manage 34: 747-752.

[9] Osueke C. O., Onokwai A. O., Ezugwu C. A., Uzendu P., Okunola A. A., Ikpotokin I., Micheal (2018). Design and Fabrication of an Anaerobic Digester for Biogas Production. *Journal of Civil Engineering and Technology.* 9(11).