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Biogas Production from Co-Digestion of Agricultural Wastes

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Abstract
Organic wastes are biodegradable and can serve as good biomass source to produce biogas for useful energy generation. This is achieved via anaerobic fermentation process, under the action of microorganisms which converts the organic matter mainly into methane and carbon dioxide, with small traces of impurity gasses. Biogas production rate and methane concentration can be improved by co-digestion of two or more substrates in a digester. This research work focuses on production of biogas from agricultural and domestic wastes, including cow dong, sugarcane bagasse, sheep dong and millet husk. Four different substrate combinations, A, B, C and D were formed from these biomass materials, at different ratios. Sample B, containing 50% Cow dung and 50% sugarcane bagasse, was observed to possess the highest daily biogas yield of 4524 cm^3 at day 26.This was followed by sample D, containing 25% cow dong, 25% sugarcane bagasse, 25% sheep dong and 25% millet husk and then sample A, containing 100% cow dong, with highest daily yields of 3968 and 3534 cm^3 respectively. Sample C, containing 50% sugarcane bagasse, 25% sheep dung and 25% millet husk, has the lowest biogas yield of 3246 cm^3.

Keywords; *Biogas, biomass, co-digestion, anaerobic digestion*

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I. Introduction

Biogas is a clean and safe renewable energy source that is applied as fuel for cars, in heat production for cooking or electricity generation in many countries (Taherzadeh and Karimi, 2008). Biogas is generated from biomass of various organic wastes and domestic by-products which include animal dungs and remains of plants like leaves, roots, stems, vegetable wastes, etc. The raw organic wastes undergo an anaerobic fermentation in a digester. The anaerobic digestion (AD) process has been identified as a basic way for agricultural and domestic wastes treatment to produce energy (Wäger *et al.*, 2009). Moreover, the residue obtained after the digestion process serves as safer and more efficient manure for crop production than the ordinary raw manure (Boysan *et al.*, 2015). Thus, the process is efficient in energy production, waste management and materials recycling as fertilizer, which solves part of the major global issues (Parajuli, 2011).

Burning firewood, straw and charcoal serves as the traditional energy source for domestic purposes in northern Nigeria. Apart from low energy gain and environmental un-safety, this practice can also inhibit our economic growth and society development severely (Li *et al*., 2016). Fossil fuels also face depletion risks and promote greenhouse effect. This necessitates the need to adopt renewable energy sources in addressing our energy challenges and saving our environment through reduced harmful emissions.

Moreover, waste production is an inevitable part of human life. This includes wastes from agriculture, industries, municipalities and other sectors, which can accumulate and result in several environmental and health hazards. Thus, waste management is a necessary step as a safety measure to address these environmental issuesand promote higher sustainable national development and resource recycling. Agriculture is one of the sectors that produces high amount of waste in various forms. It was estimated that 30% of agricultural products in the world are considered as wastes, and this provides abundant organic materials for biogas production (Oliveira and Franca, 2009). Thus, biogas generation is the answer to these problems, as it uses organic wastes in safe energy production to meet our growing energy demands.

Typically, the organic matter is mainly converted into methane and carbon dioxide in a multi-step degradation process called bio-methanation (Miah *et al.*, 2016). The reaction is induced and sustained by anaerobic action of bacteria, as follows;

Acetogenic bacteria:

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$$

Methanogenic bacteria:

$$CH_3COOH \rightarrow CH_4 + CO_2$$

The main compositions of biogas are methane (typically 40–70 vol.%) and carbon dioxide, with small traces of acidic gases and impurities such as nitrogen, hydrogen sulfide, water vapor and other volatile organic gases (Roonasi and Nezhad, 2016).

For efficient production, the organic waste should be heavy metals-free, as the presence of heavy metals reduces the biogas production through reduced digestion efficiency(Abdel-Shafy and Mansour, 2014).

Co-digestion involves formation of organic matters from two or more mixed substrates so as to improve biogas production rate and concentration of methane during the fermentation process (Deublein and Steinhauser, 2011). This is achieved by improving the organic loading rate (OLR) of the co-substrates involved in the process. The organic loading rate (OLR) is the rate at which the dry organic matter is fed into the digester. It is a vital factor that determines the stability of anaerobic fermentation process and biogas production rate, as digestible substrates are provided to grow and sustain the acting microorganisms. It was reported that the sensitivity of the microbial activity to light is not a well-established fact (U. C. Okonkwo *et al.*, 2016).Animal manure is commonly used as the main substrate in agricultural biogas co-digesters, with other organic materials added as co-substrates (Oreopoulou and Russ, 2007). Animal wastes compositions is determined by the animal type, their food and the external environmental conditions they live in (Achinas and Euverink, 2016).

Higher biogas production can be achieved through co-digestion of mixed organic materials. Miah *et al.* (2016) studied biogas production from a mixture of poultry litter and cow dung, where 75% poultry litter and 25% cow dung composition was found to be optimum for high biogas production. They reported that the increased biogas yield was due to reduced protein content with cow dung concentration, as the carbon-to-nitrogen (C/N) ratio increases.

Higher methane content and lower impurity gas concentration can also be achieved by co-digestion of mixed starter material, thereby improving the quality of biogas produced.Phetyim *et al.* (2015) produced biogas from a mixture of cattle manure and dog manure in an anaerobic digester. The effects of different ratios of cattle and dog manure on the volume and composition of the biogas were investigated. Higher dog manure ratio was found to increasemethane concentration and lower down hydrogen sulfide concentration, which leads to the improvement of the gas quality.

Co-digestion is also reported to reduce emission of greenhouse gas (GHG) and increase economic feasibility of biogas in generating electricity. Agostini *et al.* (2016) studied the economics and GHG emission of biogas produced from anaerobic co-digestion ofcattle manure in Italy. They reported that the co-digestion with Sorghum improved the profit gained and saved GHG. While pure energy cropsdigestion did not show any significant GHG reduction and even resulted in economic losses.

An anaerobic digesteris an oxygen-freecontainer which supports decomposition of organic matter to produce biogas. It has an outlet through which the produced biogas is connected into a collecting container. The used slurry is also collected through a separate outlet. Digesters are made from different container materials whose size depends on the need and operation. It can be made from cylinders, concrete,drums, bottle, cans, etc. The produced gas may be directly used from the digester orcollected with a separate collector. Various forms of digesters have been in use for anaerobic fermentation of organic materials to produce biogas. Hydraulic biogas digester (HBD) is widely used for biogas production through anaerobic digestion of most organic wastes. However, HBD is limited by difficulty to manage and discharge the material, and low volume of biogas produced when solid form of organic waste is used.Li *et al.* (2016) used dry fermentation biogas pool (DFBP) as a new method for small-scale biogas production. The pool is easy to build and operate, and was aimed at solving the difficulty in discharging solid organic wastes. An average of 1 m^3 daily biogas production was achieved, which was reported to satisfy the energy need for a family of 3. The method is suitable for rural waste management, energy and fertilizer production.

Despite the world advances in biogas technology and the favorable conditions that exist for its production in developing countries, the development of this technology has been limited in Sub-Saharan Africa. This is due to some setbacks that may be attributed to inadequate governments' support through sound energy policies and financing, poor public awareness on its economicsustainability and improper construction, operation and maintenance of digesters (Mohammed *et al.*).

Various organic materials have been used as substrates for biogas production (Patowary *et al.*, 2016). However, many more biomasses have not been explored adequately in this regard. Moreover, there exist many possible combinations of organic materials to be used as a mixed biomass at different ratiosfor biogas production in co-digestion process. Co-digestion has been reported to improve the quality and quantity of biogas

produced for energy generation (Phetyim *et al.*, 2015; Miah *et al.*, 2016). This research will focus on the influence of different biomass ratios on the quantity biogas produced. In this research, different ratios of cow dung,sugarcane bagasse, sheep dungand millet husk will be mixed and used as feedstock to produce biogas in an anaerobic digester.This is to investigate the effects of different substrate composition in biogas production rate.
Cow dung, millet husk, sheep dung and sugarcane bagasse are among the common organic wastes in our society. These require proper treatment for our safety and that of our environment. Moreover, they are also potential biomass materials which, if treated properly, can serve as safe and cheap energy sources.

II. Materials And Method

2.1 Sample collection

Cow dung, sugarcane bagasse, sheep dung and millet husk were the organic wastes used as the biomass for this research. The cow dung was collected from cow farm in Kazaure, Jigawa state, Nigeria. Sugarcane bagasse was collected from local sugarcane vendors and packed. It was packed in a sack and transported to the project site. Sheep dung was collected from sheep farm and used as collected.Millet husk was obtained from local millet processing sites in Kazaure. None of the materials was subjected to any heat or chemical treatment before feeding to the digester. These biomass materials were mixed at different ratios and used as the feedstock for the digesters.

2.2 Experimental procedures

SetupA: 100% cow dung
30 kg of cow dungwas weighed and added into the plastic container of 25 L capacity. This was followed 10 L of tap water, stirred and get the setup arranged.
SetupB: 50% Cow dung and 50% sugarcane bagasse
15kg of cow dungand 15kg of sugarcane bagasse was weighed and added into the plastic container of 25 L capacity. This was followed 10 L of tap water, stirred and get the setup arranged.
SetupC:50% sugarcane bagasse, 25% sheep dung and 25% millet husk
15kg of sugarcane bagasse, 7.5kg sheep dung of and 7.5kg of millet husk was weighed and added into the plastic container of 25 L capacity. This was followed 10 L of tap water, stirred and get the setup arranged.
Setup D:25% Cow dung, 25% sugarcane bagasse, 25% sheep dung and 25% millet husk
7.5kg of cow dung,7.5kg of sugarcane bagasse, 7.5kg sheep dungof and 7.5kg of millet huskwas weighed and added into the plastic container of 25 L capacity. This was followed 10 L of tap water, stirred and get the setup arranged.
Plastic containersof 25 liters capacity was used to make the digesters. The delivery tube was used to connect the produced gas into the gas flowmeter, wherethe gas will be measured. The delivery tube is equipped with a tap to regulate the flowof the gas. Thermometer was used to measure the temperature of the digestate.

III. Results And Discussion

The daily biogas yield was measured every day, after proper stirring, using a gas flow meter. The digester is stirred, for at least 1 minute,using a stirrer before taking the daily measurements of the gas volume.

Biogas yield did not start in the first four days, it only started in the fifth day, except for sample C, containing 50% sugarcane bagasse, 25% sheep dung and 25% millet husk, where it was not recorded until the sixth day. This is because the microorganisms to carry out the fermentation process need some time to be activated and start the anaerobic digestion process. The fermentation process starts as the bacteria involved exhausted the available oxygen in the digester. The delay in the first production for sample C is a result of weak activation of the bacteria, which may arise from high cellulose content of the biomass combination. Biogas generation was recorded up the 28th day, for all the biomass combinations. Figure 1 shows the daily biogas production from these biomass, of different combinations and ratios.

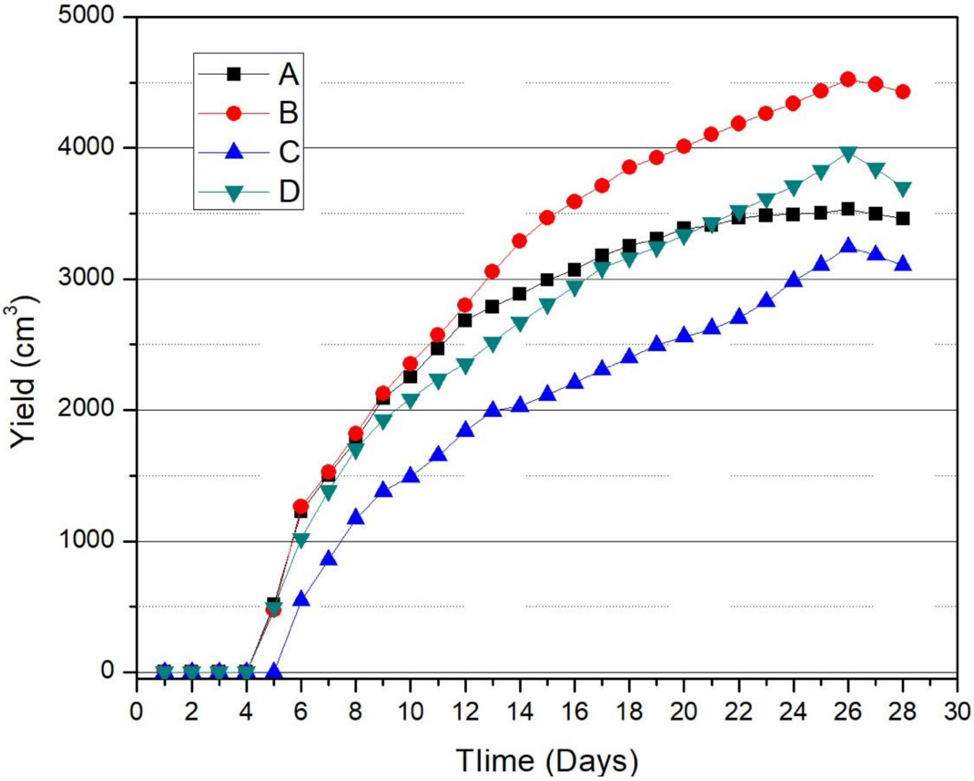

Figure 1: Daily biogas yield from different ratios of biomass; (A) 100% cow dong (B) 50% cow dong and 50% sugarcane bagasse (C) 50% sugarcane bagasse, 25% sheep dong and 25% millet husk (D) 25% cow dong, 25% sugarcane bagasse, 25% sheep dong and 25% millet husk

The daily yield was observed to increase steadily at the beginning of the gas generation. This may be attributed to the higher fermentation rate, as more substrates are produced to sustain the digestion process and produce more biomass at a time. Gradually, the production rate started to decline steadily, from around day 15, as the biomass organic content is being digested towards the end of the production days. A slight decline of the daily yield was observed, around day 26, just before the production ceases, as the digestible substrate get exhausted.

Sample B, containing 50% Cow dung and 50% sugarcane bagasse, was observed to possess the highest daily biogas yield. It has a highest daily yield of 4524 cm^3at day 26. This may be a result of lower protein content of the combination, which optimizes the carbon-to-nitrogen (C/N) ratio, as suggested by Miah *et al.* (2016).U.C. Okonkwo *et al.* (2016)reported that 30:1 is the optimum C/N ratio for highest biogas production. This was followed by sample D, containing 25% cow dong, 25% sugarcane bagasse, 25% sheep dong and 25% millet husk and then sample A, containing 100% cow dong, with highest daily yields of 3968 and 3534 cm^3respectively.Sample C, containing 50% sugarcane bagasse, 25% sheep dung and 25% millet husk, has the lowest biogas yield. This may be an effect oh high cellulose content in the combination.

IV. Conclusion

Biogas is produced from anaerobic digestion of different biomass combinations, at different ratios. The biomass include cow dong, sugarcane bagasse, sheep dong and millet husk. The first production was recorded at day 4, except for sample D which starts at day 5, and continuous until day 28. Highest daily biogas yield was observed for sample B, followed by sample D and then sample A, with sample C having the lowest daily yield.The result shows the potentials of sugarcane bagasse as good biomass source, especially as co-substrate with cow dong. This is because biomass constituent significantly affect the biogas yield of a substrate through C/N ratio.

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