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Optimization of biogas from chicken droppings with *Cymbopogon citratus*

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ABSTRACT

Optimization of biogas production and quality from chicken droppings by anaerobic co-digestion with *Cymbopogon citratus* was investigated. The anaerobic digestions of chicken droppings, chicken droppings with *C. citratus* as well as *C. citratus* alone were carried out for a period of 30 days at an average ambient temperature of 33.1 ± 2 °C using identical reactors (A–C) respectively. Results obtained indicate that chicken droppings produced on the average 1.8 L/kg/day of biogas, co-digestion of chicken droppings and *C. citratus* produced 1.3 L/kg/day of biogas while *C. citratus* alone produced 1.0 L/kg/day with estimated average methane content of 41.71%, 66.20% and 71.95% for reactors A–C respectively. The water boiling rates of biogas from chicken droppings, chicken droppings with *C. citratus*, and *C. citratus* alone were 0.079 L/min, 0.091 L/min and 0.12 L/min respectively, after the gases were scrubbed with water and slaked lime. It was observed that notwithstanding the higher biogas volumetric yield from chicken droppings digested alone, the co-digestion of chicken droppings with *C. citratus* had better gas quality with respect to the methane content present and cooking rate. This study has shown that the methane content of biogas from animal manure substrates could be improved by co-digestion with energy plants.

1. Introduction

Inadequate energy supply and environmental pollution are gargantuan problems confronting Nigeria and many other developing nations of the world. The energy demanding lifestyle of the modern world calls for the generation of energy from alternative sources that are renewable and eco-friendly [1]. The abundant hydrocarbon natural resource (crude oil and natural gas) in Nigeria is the mainstay of over 80% of revenues to the nation. However, this has neither served as a catalyst for economic growth nor the major source of energy in the mix of energy supplies. Rising crude oil prices, environmental pollution resulting from the exploration, processing and utilization of crude oil and its products have forced nations of the world to think about alternative sources of energy. Economic growth and the resultant heavy consumption of natural resources are responsible for pollution, global warming and production of acid rain etc [2]. There is a consensus of opinion that achieving the Millennium Development Goals (MDGs) in Africa will require a significant expansion of access to modern and alternative renewable energy [3]. Biogas energy could serve this purpose and can also be managed by locally available resources and simple technology especially for rural villages [3]. Furthermore, the need for adequate sanitation and energy especially in sub-Saharan Africa where only 36% of the population is served with improved sanitation facilities and only 58% are served with a safe and clean water supply [4,5] has made biogas technology a welcome development.

Anaerobic digestion is one of the few biotechnologies that can simultaneously produce bioenergy (as methane biogas), reduce environmental pollution and recycle nutrients. However, the industrial viability of this process requires a suitable combination of physical and chemical process parameters and a low-cost substrate, hence the need for process optimization. Attempts have been made to improve biogas production using mixed co-substrates. Anaerobic co-digestion of a simulated organic fraction of municipal solid wastes and fats of animal and vegetable origin has been reported [6]. A substrate of kitchen waste with cow manure has been used to achieve a yield increase of 44% [7]. Kaparaju and Rintala [8] have examined the co-digestion of pig manure, potato tuber and its industrial by-products. The co-digestion of fruit and vegetable wastes, cattle slurry and chicken manure or sewage sludge for

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Table 1
Characteristics of the substrates before anaerobic digestion.

S/N	Parameter	Poultry droppings	Poultry droppings + *Cymbopogon citratus*	*Cymbopogon citratus*	Inoculum
1	pH	6.3 ± 0.1	5.1 ± 0.1	6.5 ± 0.1	7.8 ± 0.1
2	Total solids (%*w*/*w*)	68 ± 5.6	19 ± 2.1	3 ± 0.1	1.62 ± 0.1
3	Volatile solids (%*w*/*w*)	37.4 ± 3.2	8.6 ± 1.6	1.2 ± 0.01	90.72 ± 5.9
4	Ash (%*w*/*w*)	2.43 ± 0.1	2.8 ± 0.1	3.1 ± 0.1	1.24 ± 0.1
5	Total Kjeldahl nitrogen (gN/kg)	72.2 ± 8.5	38.5 ± 2.9	12.0 ± 1.8	14.2 ± 1.9
6	Alkalinity (g/L)	28.2 ± 2.3	16.0 ± 2.1	0	4.4 ± 0.4
7	C:N ratio	4.2 ± 0.2	42.2 ± 3.6	76.4 ± 4.8	3.8 ± 0.3
8	Protein (%*w*/*w*)	4.2 ± 0.2	3.1 ± 0.1	0.84 ± 0.1	2.6 ± 0.1
9	Carbohydrate (%*w*/*w*)	2.4 ± 0.1	12.3 ± 0.2	16 ± 1.2	2.2 ± 0.1

biogas production has also been studied [9,10]. The best combination of various substrates for optimal yield and gas quality remains a big problem despite the enormous number of potential substrates. The technical and economical feasibility of an industrial anaerobic digestion plant has been reported to be dependent on the methane content of the biogas generated [11]. Co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nutrient balance [12,13].

Cymbopogon citratus popularly known as lemon grass is an aromatic plant belonging to the family *Gramineae* and the genus *Cymbopogon* [14]. It is a perennial grass growing to a height of about 1 m. The leaf-blade is linear, tapered at both ends and can grow to a length of 50 cm and width of 1.5 cm [15]. The leaf-sheath is tubular in shape and acts as a pseudo stem. It is native of the warm temperate and tropical regions of the old world. Lemon grass can tolerate a wide range of soils and climatic conditions but grows more vigorously on fertile well drained sandy loam soil [15].

According to Ref. [16], lemon grass is used for many medical and industrial applications due to its essential oil and citral content. However, after using lemon grass for its useful purposes, it is often discarded as solid waste in huge quantities. At the moment little or less is known on the re-use of lemon grass waste. There is also paucity of information on the potential of *C. citratus* (lemon grass) for biogas production. Though chicken droppings could yield relatively large amount of biogas, its biogas usually contains a lot of impurities. Co-digesting chicken droppings with some energy plants could contribute to improving the quality of biogas generated. This study was therefore carried out to investigate the effect of co-digesting chicken droppings and *C. citratus* (lemon grass) on biogas quality (methane content and heating capacity). The viability of large scale anaerobic plants depends not only on biogas yield but also improved gas quality [17].

2. Materials and method

2.1. Collection and preparation of substrates

Chicken droppings were obtained (fresh and free from impurities such as wood filings) from the Poultry Department (Deep litter section) of the National Animal Production Research Institute, Shika-Zaria, Nigeria and were transported to the research site. The *C. citratus* (lemon grass) on the other hand was obtained from gardens around some houses within Area BZ staff quarters, Ahmadu Bello University, Zaria. The total solids and volatile solids of substrates were determined using standard methods described in Ref. [17,18]. Following the procedure in Fantozzi and Buratti [11]; APHA [18] the carbon and nitrogen contents were determined using a TruSpec-CHN LECO analyzer. Ash content was determined using TGA 701 LEO analyzer [11,18]. Total Kjeldahl Nitrogen (TKN) was measured using standard methods [18]. Protein and carbohydrate contents were measured using Soxhlet extraction and micro-Kjeldahl methods described in Uzodinma and Ofoefule [19]. With slight modification, the procedure used in Kaparaju and Rintala [8] was used to measure the methane content of biogas by gas chromatography (GC) (Agilent Technologies 6890N, Ca, USA) using flame ionization detection (FID) fitted with a Porapak Molsieve 5A columns. Helium was used as carrier gas with a pressure of 3.0 kg/cm^2 and flow rate of 15 ml/min. Injection and detection temperatures were set at 105 °C and 150 °C respectively. Detailed characteristics of the substrates are shown in Table 1. The lemon grass obtained was kept in a dry bucket and was allowed to degrade for 40 days, before it was crushed to smaller particles (about 2 inches or less) using hammer mill. Similar procedure was used for field grass [19]. The poultry droppings were sun dried for 15 days, followed by mechanical crushing with mortar and pestle. Lemon grass was allowed to degrade for 40 days inorder to partially decompose its lignin, cellulose and other fibrous tissues to enhance a better performance during the anaerobic digestion.

2.2. Experimental device

Three 25 L-biogas reactors (A–C) each of height 0.5 m and diameter 0.25 m were fabricated from galvanized steel. Galvanized steel was used as building material because of its strength and durability in acid or basic environment. Five different holes were bored on the lid of the digester for insertion of temperature and pH probes using threaded steel adapters and rubber stoppers to avoid gas leakage. The cylindrical shape was adopted to enhance better mixing. The tank was air tight and was clearly placed above the ground level where it was exposed to sunlight for partial heating. Three 12.1 L gas holder tanks each of height 0.25 m and diameter 0.25 m were fabricated from thin sheet metal and were used to temporarily store the biogas until it was used to produce heat or used to replace or supplement the supply of cooking gas. Plastic hose was used to connect the digester to the gas collection system and the biogas stove burner while plastic valves were installed to control the gas flow. The gas holder stores the biogas and allows the volume of biogas produced to be measured through the indirect measurement of a liquid column height. The digester and gas holder were designed, built and operated by the methods described in Ref. [17,20] with slight modifications. The composition of biogas (CH_4 and CO_2 contents) was determined using a gas chromatography (GC) (Agilent Technologies 6890N, Ca, USA). Biogas composition measurement was taken two times a week in duplicate from each digester. A 100 μl gas tight syringe was used to take biogas samples from the digesters head space after releasing the gas. This was followed by injecting the biogas sample into the GC [21,22]. The other materials used in this study include pH meter model pHS-2S, (Shanghai Jinyke Rex, China) for measuring the pH of slurry every week day throughout the retention period, and Uniscope 2/1 °C thermometers was used to obtain daily temperature of the digester as well as the daily ambient temperatures of the environment. The schematic of the set-up is as shown in Fig. 1.