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Comparative Analysis of Co-Digestion of Cow Dung and Jatropha Cake at Ambient Temperature

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Abstract

Co-digestion of cow dung and Jatropha cake at different mix-ratio in anaerobic digestion was studied at ambient temperature. Cow dung and Jatropha cake were digested at 100%; 75% and 25%; 50% and 50%; 25% and 75%; and 100% using the percentage volatile solid of each substrate. The experiment was carried out in batch digester. The digester was fed with cow dung and Jatropha cake mixtures calculated for the selected percentage based on the volatile solid concentration of the substrates. Co-digestion of cow dung and Jatropha cake at 75% cow dung and 25% Jatropha cake at ambient temperature released the highest biogas and methane yields in organic dry matter form, while the highest fresh mass biogas and methane were found in the mix-ratio that has 100% Jatropha cake. 100% Jatropha cake released the highest gas while co-digestion at 50% cow dung and 50% Jatropha cake came second. Therefore, for optimal co-digestion of cow dung and Jatropha cake at ambient temperature 50% cow dung and 50% Jatropha cake is recommended.

Keywords: Co-digestion; Batch experiment; Cow dung; Jatropha cake; Ambient temperature

Introduction

Energy is a necessary commodity in life, and the demand is constant for meeting domestic, social and industrial wants. To keep socio-economic life in motion, there is need for constant and adequate provision of energy for house-hold and industrial needs. Failure or shortage of energy supply makes life hard and unbearable [1]. In a contemporary society, larger amount of energy is needed for domestics, industries, services and transportation. However, neither oil nor any of the other fossil fuels, such as coal and natural gas, are unlimited resources. The combined consequences of greater demand and depleting resources require high monitoring of the state of affair of energy. Efficiency, dependency, security and environmental concerns are other reasons why intellectual knowledge of energy state is necessary [2].

Energy that is generated in accordance with nature and replenished without variation is called renewable energy. In order to tackle the challenges of climate changes, the generation of renewable energy will be one of the major challenges that mankind will encounter over the coming decennary [3]. Various forms of renewable energy exists, they can be generated directly or indirectly from the sun, or from heat generated deep inside the earth. These include energy liberated from solar, wind, biomass, geothermal, hydropower, ocean resources, solid biomass, biogas and liquid bio-fuels. Biomass can contribute immensely to the future energy needed in a sustainable manner. There are several methods of converting biomass to energy depending on the physical nature and chemical composition of the feed stocks, and the energy service required (transport fuel, heat, power). Current production of electricity and/or heat from sludges, liquid and wet organic materials requires anaerobic digestion as the best-suited option, although its economic case depends majorly on the availability of low-cost feedstock [3].

Anaerobic degradation or digestion is the breaking down of biomass by a concerted action of broad range of microorganisms without oxygen to liberate biogas [4]. Biogas is a mixture of different gases released as a result of the anaerobia micro-organic activities on both domestic, industrial, and agricultural residues, with different proportion of methane, carbon dioxide, nitrogen, hydrogen sulphide, oxygen, hydrogen, ammonia and water vapour [5,6]. Anaerobic Digestion (AD) could be a better idea for agricultural residues utilization because it produces both biogas and a residue which has been considered as an organic fertilizer (Bio-fertilizer) with high NPK concentration [7]. Conversion of wastes to energy needs serious attention to boost energy supply and reduce environmental pollution [8].

Nigeria as a developing country releases huge amount of domestic, industrial and animal waste, and agricultural residues daily in order to meet their basic needs. Hence, there is need to adopt a new technique (Biogas Technology) of managing them and at the same meet the present needs of energy in the country [9]. *Jatropha caucus* (Figure 1a) is getting more popularity worldwide because of its uses [10]. The fruit shell is reported to contain about 34% cellulose, 10% hemi cellulose and 12% lignin and is good in minerals [11]. Researches on the properties and compositions of Jatropha seed show that Jatropha oil can be used for fuel purposes [12]. The Jatropha press cake is obtained after removing the oil from the seed either chemically or mechanically. Jatropha seed cake (Figure 1b) is mostly a waste because of the presence of toxic material (crucin, saponins etc.) in the cake [13]. It cannot be used as animal feed nor can it be used directly as fertilizer in

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agricultural farming. Therefore, proper utilization of the cake for biogas production is therefore required to overcome the problem. Jatropha press cake is a good feedstock for in anaerobic digestion because it is rich in organic matter; containing between 56%-64% crude protein [14]. Biogas production from Jatropha press cake is about 60% higher when compared to the biogas generated from cow dung, with better calorific value as it had more methane [15].

Figure 1: 1a: Jatropha seed and 1b: Jatropha seed de-oiled cake.

Studies show that, some agricultural residues undergo anaerobic digestion problem because of the presence of lignocellulose in them and resulting into low nitrogen content [16]. In order to improve the biodegradation and C:N ratio of these agricultural residues, pre-treatment and co-digestion with animal dung is highly recommended to obtain an optimum gas yield [3]. Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. The most common circumstances is when a major amount of most important substrate (e.g. manure or sewage sludge) is combined and digested in conjunction with lesser importance amounts of a single, or a variety of added substrates. Better digestibility, increases biogas production/methane yield arising from availability of extra nutrients, better buffer capacity with stable performance as well as a more effective usage of equipment and cost sharing have been highlighted as part of the advantages of co-digestion [17-19]. Studies conducted by Adebayo et al., Periyasamy and Nagarajan and Callaghan et al. [20-22] on co-digestion of cattle slurry with maize stalk, co-digestion of orange peel and Jatropha de-oiled cake and co-digestion of waste organic solids respectively showed an improved biogas and methane yields compared to single digestion. Also one of biogas substrate that is available in large quantity is cow dung. Cow dung is one of the most suited materials for biogas plants because of the methane producing bacteria already contained in the stomach of ruminants. The specific gas released, however, is lower and the proportion of methane is around 65% because of pre-fermentation in the stomach [23]. Therefore, appropriate mix ratio of these materials can result into an improved yield of biogas production which can go a long way to solve energy problem. This work studied the appropriate mix ratio of the Jatropha cake and cow dung for higher biogas yield in a batch digester.

Materials and Method

Materials

The materials and equipment used for the study include; substrates (cow dung and Jatropha cake), five 5-liters containers, Gas analyzer (Multi 4 Stage Biogas Analyzer), five tyre tubes, flexible pipe, five thermometers (-10 to 1100), five pressure gauge (sphygmomanometer), digital weighing scale and five 2-ways taps. The design of a laboratory batch digester by Barthelmeß [24] was adopted and five 5-liters containers/gallons were used for the experiment, which served as the main digester since it is an experiment to investigate mix ratio between two substrates. The substrates for the research were sourced locally. The cow dung was collected from the cow market of the Mandate market in Ilorin while the Jatropha cake was sourced from Agricultural and Bio/systems Engineering Department laboratory of the University of Ilorin, Ilorin, from the students doing research on biodiesel from Jatropha seeds. The substrates were sent to laboratory for proximate analysis.

Methodology

Simultaneously, five digesters (A, B, C, D and E) as shown in Figure 2 were set up and observed concurrently at an ambient temperature and pressure. The substrates were checked for stones and other unnecessary materials before mixing and weighing of the substrates was done using a digital weighing scale. The substrates were mixed with water in a ratio of 1:2 of waste to water by weight which had been found the most suitable mixture for the optimum biogas production and methane concentration [25] and were properly stirred before been mixed in varying proportions. The quantity of the substrate loaded in the digesters are as follows: Digester A 7 kg of Cow Dung; Digester B 5.25 kg of Cow Dung and 1.75 kg of Jatropha cake; Digester C 3.5 kg of Cow Dung and 3.5 kg of Jatropha cake; Digester D 1.75 kg Cow Dung and 5.25 kg Jatropha cake and Digester E 7 kg Jatropha cake. The ratio of the Cow dung and Jatropha cake that were examined as indicated in Table 1 was adopted from Chrish and Julian [26,27].

Figure 2: Batch experiment set-up.

Treatments	Mixture Proportions
A	100% Cow Dung
B	75% Cow Dung and 25% Jatropha Cake
C	50% Cow Dung and 50% Jatropha Cake
D	25% Cow Dung and 75% Jatropha Cake
E	100% Jatropha Cake

Table 1: Proportions for different treatments.

Daily ambient temperature and pressure together with the slurry temperature and pressure were taking by 12 noon daily. The retention time for the experiment was 30-40 days as recommended by Ostrem et al. [28]. As soon as gas production began, gas collection commenced using tyre tubes that has been properly fixed to the gas outlet from the digester. Quantity of the biogas produced was obtained with the use of Equation 3 [29].

$$R_o = \frac{R}{M} \times \% \quad composition (1)$$

$$R_o mixture = R_{CO_2} + R_{CH_4} \qquad (2)$$

$$V = \frac{R_{CO_2} \times R_{CH_4}}{P_e} \qquad (3)$$

Where:

R_o: Specific gas constant of a gas (J/kgK)

R: Universal gas constant (J/kgK)

M: Molecular mass of the gas concerned

$R_{o\ mixture}$: Total specific gas constant of the assumed biogas composition (i.e. CH_4 and CO_2)

P_e: Estimated daily pressure of the digester

$T_{digester}$: Estimated daily temperature (°C)

V: Volume of biogas generated (m^3).

Results and Discussion

Proximate analysis of substrate

The result of the proximate analysis of the substrates is shown in Table 2. The organic dry matter of the substrates is considerably high, ranging from 84.80% to 92.22%. This indicates that there is high buffering capacity of the selected substrates for adequate anaerobic process. Cow dung has the highest C/N ratio of 15.7 while Jatropha cake has C/N ratio of 10.2.

Parameters	Cow Dung	Jatropha Cake
Dry Matter, DM (%)	40.69	96
Organic Dry Matter, oDM (%)	84.8	92.22
Potassium (%)	1.12	3.22
Moisture Content MC (%)	59.31	4
Nitrogen (%)	1.76	3.69
Phosphorous (%)	0.06	2.09

Table 2: Proximate analysis of the substrate.

Both of them have very high C/N ratio and their co-digestion formed an excellent mixture of substrate for biogas yield. This experiment follows the submission of Verma [30] that optimum C/N ratio of the substrates can be achieved by co-digestion of high and low C/N ratios such as organic solid waste mixed with sewage or animal manure.

Biogas and methane yields

The cumulative fresh mass biogas yield, organic dry-matter biogas yield, fresh mass methane yield and organic dry-matter methane yield from co-digestion of cow dung and Jatropha cake at different mix ratio are shown in Figures 3-6. There was no evidence of gas production from all the digester during the first four days of the experiment. It may be as a result of inoculums being in lag phase or the methanogens undergoing a metamorphic process and consumed methane precursors released from the preceeding activities as suggested by Lalitha et al. [31]. At the initial stages of the biogas production process, acid forming bacterial released volatile fatty acids (VFA) and this reduced the pH and diminished methanogens and methanogenic bacteria [32,33].

During the co-digestion of cow dung with Jatropha cake at different mix ratios at ambient condition, the fresh mass biogas yields were found to be 2248.2, 2780.7, 4318.7, 3677.2 and 5549.5 lN/kgFM for A (100% CD), B (75% CD and 25% JC), C (50% CD and 50% JC), D (25% CD and 75% JC) and E (100% JC) respectively (Figure 3); the organic matter biogas yield were 6515.4, 8058.9, 7138.7, 4952.1 and 6268.4 lN/kgoDM for mix-ratio A, B, C, D, and E respectively (Figure 4). Likewise, the fresh mass methane yield from mix-ratio A, B, C, D, and E were found to be 1301.7, 1576.7, 2656, 2213.7 and 3479.5 $lNCH_4$/kgFM (Figure 5), and organic dry matter methane yield of 3772.4, 4569.4, 4390.3, 2981.2 and 3930.3 $lNCH_4$/kgoDM for mix-ratio A, B, C, D, and E respectively (Figure 6). Higher organic matter biogas and methane yields were obtained at digester B (75% vs. of cow dung co-digested with 25% vs. of Jatropha cake).

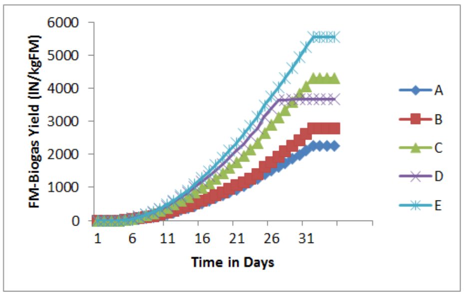

Figure 3: Fresh mass biogas yield.

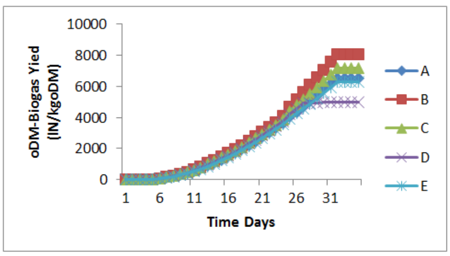

Figure 4: Organic dry-matter biogas yield.

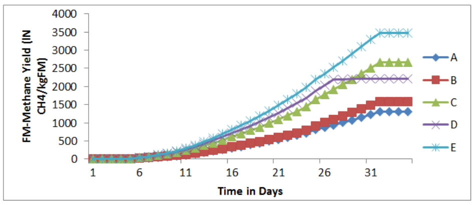

Figure 5: Fresh mass methane yield.

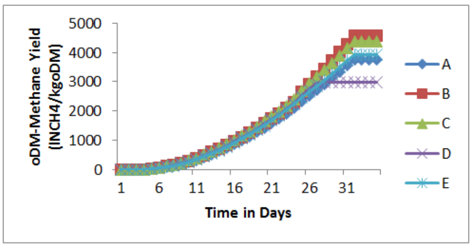

Figure 6: Organic dry matter methane yield.

This is because higher mixing ratios meant higher quantity of Jatropha cake in the mixture, which also implied increased lignin content and this made digestion activities to be more difficult for the anaerobic bacteria. Thus, co-digestion of cow dung with Jatropha cake showed increase in the yields from the organic dry matter contents of the selected substrates. This is in line with previous reports by Adeyanju, Callagham et al., Babel et al. and Ilori et al. [34-36] that co-digestion improved the biogas yield when compared with digestion of the substrate individually. Considering the fresh form of the yields, digester E (100% Jatropha cake) produced the highest biogas (5549.5 lN/kgFM) and methane (3479.5 lNCH4/kgFM). This means that co-digestion of Jatropha cake with cow dung has effects on C/N ratio of Jatropha cake, thereby reduced the fresh biogas and methane yield of the Jatropha cake during co-digestion. This agreed with findings of Adebayo [37] which stated that process parameters had influence on biogas yields. Digester C (50% cow dung and 50% Jatropha cake) came second in both organic dry matter and fresh mass biogas and methane yields.

Conclusion

The research revealed that co-digestion of cow dung and Jatropha cake to get an improved organic dry matter and fresh mass biogas and methane will be at its best when it is 50% of cow dung and 50% of Jatropha cake.

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