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THE EFFECT OF PARTICLES SIZE ON BIOGAS PRODUCTION

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Abstract

The study on the effect of particles size on biogas production has been conducted. Substrates consisted of pre-treated water hyacinth with drying and grounded to fine particles of (0.001and 0.05 mm) and chopped water hyacinth to small particles of (1.0 and 2.5 mm). The reactor digesters were operated at mesophilic temperature ranges of 25 °C to 32 °C with retention time of 23 days. Results showed that highest biogas production occurred with the most finely grounded substrate (0.001 mm) which recorded 0.39 liters of biogas with 70 % CH_4 followed by the grounded particles of 0.05 mm yields 0.34 liters with 66 % CH_4 .while the lowest biogas production was observed from the chopped particles of 2.5 mm producing 0.24 liters of biogas with 55 % CH_4. Further observation revealed that methane yields increased by 21 % when the substrates were pre-treated by grinding into very fine particles compared with the chopped substrate. The results suggest that small particle size favours methane yield.

Key words: Anaerobic, substrates, water hyacinth, fish waste.

1 Introduction

Anaerobic digestion of energy crops, residues and waste is of increasing interest in order to reduce the greenhouse gas (GHG) emissions and to facilitate a sustainable development of energy supply. Currently, the world's energy markets rely heavily on the fossil fuels coal, petroleum crude oil, and natural gas as sources of energy, fuels, and chemicals [1]. Production of biogas provides a versatile carrier of renewable energy, as methane can be used for replacement of fossil fuels in both heat and power generation and as vehicle fuels [2]

The production of biogas through anaerobic digestion is offers significant advantages over other forms of bioenergy production. This includes the generation of renewable energy, a reduction of GHG, a reduced dependency on fossil fuels, job creation, and closing of nutrient cycle [3]. It transforms organic waste material into valuable resources while at the same time reducing solid waste volumes and thus waste disposal cost [4]. Biogas as a renewable energy source not only improves the energy balance of a country but also contributes to the preservation of the natural resources by reducing deforestation and to environmental protection by reducing pollution from waste and use of fossil fuels [5].

Various factors such as pH, digestion temperature, Carbon to Nitrogen ratio (C: N), loading rate, hydraulic retention time (HRT), Volatile fatty acids (VFA), feedstock quality (feedstock particles size), etc, influence biogas production.

A number of researchers have studied biogas production and came up with various observation. [6] reported that methane formation takes place within a relatively narrow p H range from 6.5 to 8.5 with an optimum interval between 7.0 and 8.0, the process is severely inhibited if the p H decreases below 6.0 or rises above 8.5. The pH of the digester is a function of the concentration of volatile fatty acids produced, bicarbonate alkalinity of the system, and the amount of carbon dioxide produced as stated by [7].

Hydraulic retention time varied with the effects of temperature. [8] reported that anaerobic digestion can be developed for different digestion temperature ranges including mesophilic temperature approximately 25 °C to 37 °C for retention time of 20 to 40 days, and thermophilic temperatures ranging from 43 °C to 60 °C for retention time of 15 to 20 days, however the thermophilic temperatures range is worth considering because it will lead to give faster reaction rates, higher gas production and higher rates of destruction of pathogens.

In the case of C: N ratio, 25-30, :1 is optimal for biogas production [9].

Various researchers has investigated the influence of the different waste particles on anaerobic digestion [10, 11]. It is known that the reduction of particles size and the resulting increase in their specific surface lead to increase in gas production especially in the case of digesting the substrates having high contents of slowly biodegradable materials.

The effect of particle size of seven agricultural and forest residue used as feedstock for biogas generation through anaerobic digestion were investigated in batch digesters at 37 °C. Among the five particle size (0.088, 0.40, 1.0, 6.0 and 30.0 mm), studied, maximum quantity of biogas was produced from raw materials of 0.088 and 0.40 mm particles [12].

The effects of particles size of sisal waste and its degradation and biogas production potential were investigated in batch anaerobic digestion with fibre sizes ranging from 2 to 100 mm at an ambient temperature of 33 °C. The results confirmed that methane yield was inversely proportional to

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particle size. An increase of 23 % was observed when the fibres were cut to 2 mm size and yield 0.22 m^3 CH_4 /kg volatile solids, compared to 0.18 m^3 CH_4 /kg volatile solids for untreated fibres [13].

Likewise, the production of biogas from anaerobic co-digestion of sisal pulp and fish waste with the same feed-stock particles size was studied and the results yield highest methane of 0.62 m^3 /kg VS from co-digested mixture of 33 % fish waste and 67 % sisal pulp [14]. However, information on the influence of the particles size of dried water hyacinth on anaerobic digestion is scarce and scant.

Thus the aim of this research was to investigate the effect of particle size when dried water hyacinth was digested for biogas production carried out under mesophilic temperature range with retention time of 23 days.

2 Materials and Methods

2.1 Sample Preparation

Samples of water hyacinth (WH) were taken from Lake Victoria, Mwanza and allowed to be dried under the sun for 2 months.

2.2 Inoculum

Anaerobic inocula used for digester start up was taken from Vingunguti slaughtering house in Dar es Salaam consisted of small intestine cow dung and blood with the ratio of 1:1.

2.3 The principle of experiment

The principle of the biogas production of the feed stocks used in this study is shown in figure 6. About 15 gm of feedstock blend was mixed with 300 ml of inoculums and 150 ml of water. The experiment was carried out under mesophilic temperature. The increase in gas chamber pressure in the test digester resulting from the production of carbon dioxide (CO_2) and methane (CH_4) was measured. On the other hand, the amount of microbiologically produced carbon was calculated from the net gas production and the net inorganic carbon (IC) formation in excess over blank values (BS EN ISO 11734:1999).

2.3.1 Biogas Production

The biogas production was determined by measuring pressure in the gas chamber using pressure manometer and recorded on daily basis. Parameters for biogas production were calculated as follows:

The daily biogas was calculated by using the headspace pressure of the reactor, after measuring the head space pressure, the biogas in the head space was released by calibrated syringes and was done so carefully to prevent gas exchange between the headspace and ambient air. Then the pressure in the headspace was measured as the initial condition for the next measurement. Daily pressure differences were converted into biogas volume using equation (1) : [15].

$$V_{P_{i,Biogas}} = \frac{(P_{i,initial} - P_{i-1,final}).V_{head}.C}{RT} \quad (1)$$

Where:-

$V_{P_{i,Biogas}}$ Is the daily biogas volume in day *i*, L.

$P_{i,\ initial}$ is absolute pressure before release in day *i*, Pa

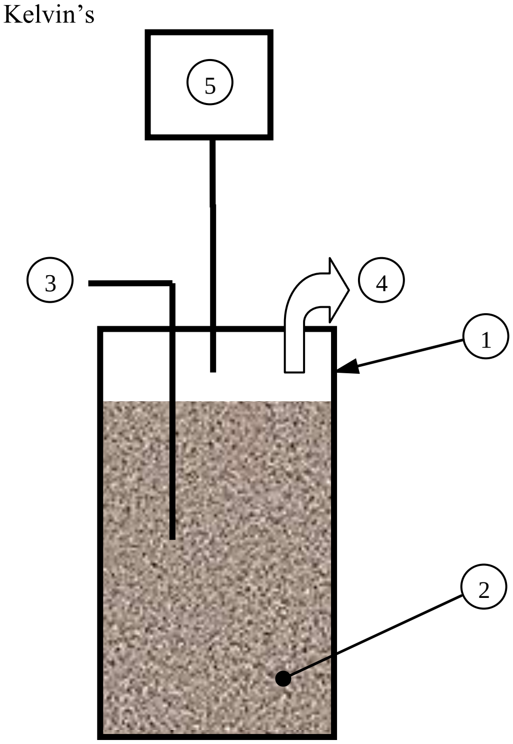
$P_{i-1,\ final}$ is absolute pressure after release in day *i* -1, Pa

V_{head} is the volume of reactor head space in liters,

C is the molar volume, 22.41 L/mol

R is the universal molar gas constant [8,314 J/(mol·K)]

T is the absolute reactors incubation temperature, in Kelvin's



KEY
1.Digester
2.Digestate
3.Temperature probe
4.Gas measuring point
5.Manometer

Figure1: Experimental layout diagram for the digested samples

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2.4 Experimental Materials

The feedstock used in this study was pulverized and chopped water hyacinth with four different particles size. Water hyacinth leaves was collected from different growth stages, allowed to be cleaned and dried under the sun for 2 months, then grounded into very fine particles (0.001and 0.06 mm) using a grinding mill, as shown in the plate 2 (a and b), followed by oven drying at 60 °C for 3 hours, while the second experiment dried and chopped to small particles (1.0 and 2 mm) water hyacinth were used with the same preparation procedures as shown in the plate 2 (c and d)

a) 0.001mm

b) 0.05 mm

c) 1.0 mm

d) 2.5 mm

Plate 2: Feedstock samples used in biogas experimentation

2.4.1 Experimental set up

The experimental set up for the digested feedstock consisted of four digester reactors for each substrate. The volume of inoculum was kept constant at 450mls for all digesters. The schematic diagram of the experimental set-up of the biogas production is presented in the Plate 5. The temperature in the digester was measured on daily basis using YC-747UD thermometer datalogger with K-Type thermocouples. The Pressure gauges were employed for monitoring biogas production while bucket with sand acted as thermal insulation to control temperature inside the digester reactors.

Plate 3: Experimental set up for digester reactors

2.4.2 Experimental Procedures

The feedstock was put in the beaker and weighed in corresponding ratio. 15g of feedstock was digested in each reactor. Measured feedstock was fed in the reactors and inoculum consisted of cow dung and blood mixed with 150 ml of fresh water were also poured into the 500 ml reactor to about 90 % of the reactor volume keeping the volume and gas chamber constant in all the digesters.

The reactor top cover connected with the manometer and temperature probe was then closed and kept in air tight condition so as not to allow the oxygen inside the reactor which affects anaerobic digestion process. The reactor pressure and temperature was recorded on a daily basis and the gas was measured after every 48 hours depending on the pressure readings. The volume of the generated biogas was measured by the graduated 20 ml plastic syringe and recorded, the gas composition of 5ml samples of the biogas was estimated by the absorption of the carbon dioxide and hydrogen sulphide in a concentrated alkaline solution (NaOH) using serum bottles. The biogas taken from the digester was injected in the serum bottles and shaken for 2 min where only CH_4 is obtained after absorption of carbon dioxide and hydrogen sulphide gases as proved by [14].

3 RESULTS AND DISCUSSIONS

3.1 Biogas production

The trend of the daily biogas production with time from all the digester reactors is shown in Figure 7. Biogas production for finest particles digested samples commenced within two days while the chopped samples delayed. The fermentation slurry of pulverized water hyacinth was observed to produce the highest quantity of biogas of 0.39 liters followed by grounded particles size of 0.05 mm as 0.34 liters. This performance confirms the earlier reports by other researchers that combining cow dung with plant wastes catalyzes the biogas production with consequent increased output [16-18], The lowest amount of biogas was obtained from the chopped water hyacinth with particles size of 1.0 mm and 2.5 mm as 0.29 liters and 0.24 liters respectively.

The rate of biomethanation was highest for grounded water hyacinth than others throughout the experiment; however the evolution of biogas from 2.5 mm particles size stopped after 17 days. This could be because of lack of dilution in the digestion slurry; liquid environment in the slurry is very significant as it enables easy circulation of material and contact between the bacteria and their food as reported by [16]. Also large particles have relatively low surface area and as such the microbial/enzymes substrate contact was reduced, resulting in poor biogas generation as stated by [19]. Also [17] reported that cumulative biogas production was higher for a particle size of 6.4 mm than for a particles of 12.7 mm.

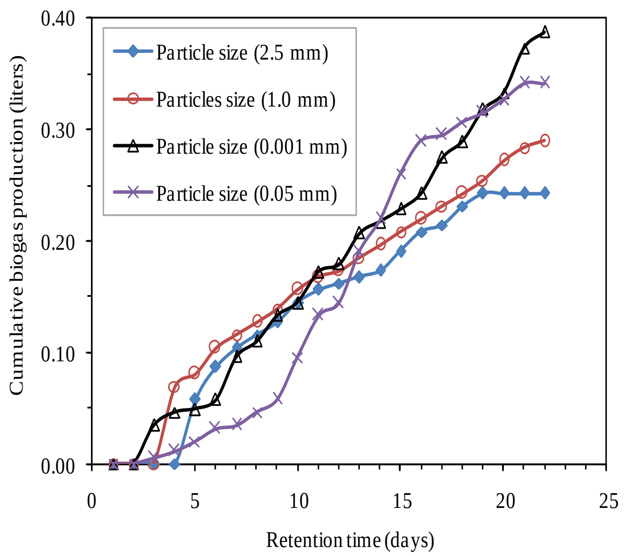

Figure 4: Biogas production trend for the digested samples

3.2 BIOGAS COMPOSITION

Figure 8 shows total methane production at different proportions where the average maximum methane content of the biogas produced from 2.5 mm particles size was 55 %; chopped water hyacinth with 1.0 mm particles size was 60 %, for pulverized water hyacinth with 0.001 mm particles size used was 70 %, and grounded water hyacinth with a particles size of 0.05 mm was 66 %. The results highlight the greater methane contents in the pulverized water hyacinth with 0.001 mm particles size as 70 % followed by the grounded water hyacinth with 0.05 mm particles size as 66 %.

Generally the cumulative methane concentration decreased with the increase of particles size; however the most grounded particles gave relatively higher concentration of methane than chopped particles. The big increase of digestion products with the decrease in particles size corresponded with the increase of microbe substrate contact. In the substrates with small particles sizes the micro-organism and their enzymes were in contact with the substrate material hence higher utilization of material was achieved.

The results are similar with the observation made by [20] who reported that water hyacinth which has been dried and grinded into very fine particles generates biogas that has greater methane content of more than 69.6 % than digested dung. Figure 6 shows that the maximum methane was obtained between 7[th] and 15[th] days. This is because, during the first five days, the biogas contains some little amount of water vapour and a lot of CO_2 gases. Methane formation was in consistent with the pH range of balanced anaerobic digestion that requires optimum interval of 6.5 to 8.5 as reported by [6].

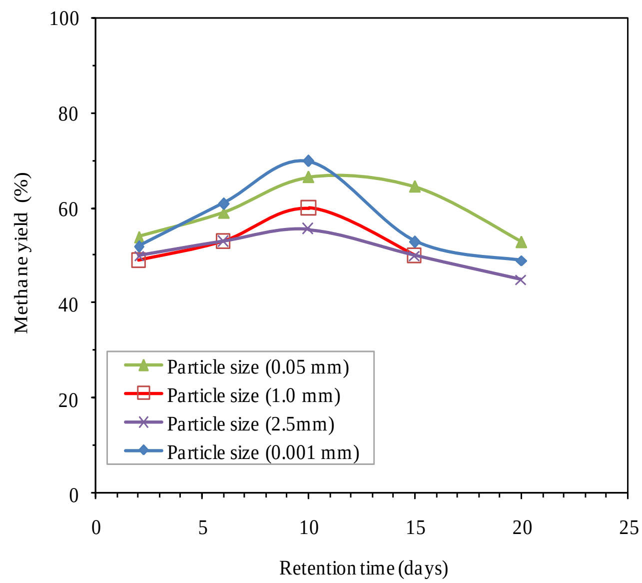

Figure 5: Biogas composition for digested samples

3.3 Conclusion

The study has shown that large amount of biogas was obtained from the grounded water hyacinth than chopped water hyacinth. The study also highlights that water hyacinth is very good biogas producer when dried and pulverized (crushed) into very fine particles (powder). Degradation of the substrate and biogas production potential of the water hyacinth could be significantly increased by pre-treatment such as reduction of particles size. These results suggest that reduction of the particles size of the substrate in conjunction with the optimized microbial growth could improve the methane yields in anaerobic digestion processes.

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