Performance Evaluation of Biogas Yields Potential from Co-Digestion of Water Hyacinth and Kitchen Waste

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Abstract—Solid wastes are generated and dump indiscriminately in Nigeria due to poor implementation of standards, thus causing environmental and public health hazards. Nigeria generates more than 32 million tons of solid waste annually, out of which only 20–30% is collected and disposed in an open dump site. Different researchers have reported that organic waste fraction of solid waste generated in Nigeria has the highest percentage which is over 50%. However, this fraction of organic waste is yet to be properly utilized for biogas production. This research work is focused on the performance evaluation of biogas potential yields from co-digestion of kitchen wastes and water hyacinth. A 0.030m³ anaerobic mild steel digester was fabricated and used to digest the composition of water hyacinth and kitchen wastes. The experiment was conducted under mesophilic temperature range and a pH range of 6.0–7.4. The results obtained show that a cumulative biogas yield of 0.0499m³ was obtained from 30kg of substrates composition of kitchen waste and water hyacinth. Besides, optimum biogas yields were obtained at optimum mesophilic temperature.

Index Terms—Biogas Yield; Kitchen Waste; Water Hyacinth; Mesophilic Temperature; pH Range; Performance Evaluation.

I. INTRODUCTION

The basic of life is energy. The most fascinating feature of any civilized society is the availability of energy for domestic, agricultural and industrial purposes [1]. The energy problem of Nigeria is affecting the entire country and thus many of the energy decisions have to be coordinated between all levels of government [2]. A more serious problem is our increasing population culminating in high energy demand and a limited rapidly depleting energy resource which has resulted in severe energy crisis [3]. The energy industry in Nigeria has severe environmental ramifications, mostly in the form of both pollution and deforestation [4].

The available energy sources in Nigeria are woods, fossil fuels, solar, wind, tidal, terra-thermal [5]. The cost of energy for domestic, commercial and industrial uses in Nigeria has risen astronomically in the past few years following the liberalization and reform of the oil industry and the energy sector as a whole [6]. This calls for serious measures and adequate policies in perfecting utilization, exploration and exploitation of our energy sources and pursuit of new alternative energy sources and its conservation. The biogas technology is one of such systems and has been found to be cost effective and environmentally sound [7]-[9].

It is defined as ecology oriented form of appropriate technology based on degradation of organic materials under suitable and stable temperature to produce a combustible mixture of methane gas known as biogas leaving behind slurry known as bio fertilizer [10]-[12]. The adoption of waste biomass to produce energy can reduce the use of fossil fuels, reduce greenhouse gas emissions and reduce pollution and waste management problems [13]-[16]. IEA [17] pointed out that by 2020, the equivalent of 19 million tonnes of oil will be available from biomass, of which 46% will be from biomasses majorly municipal solid wastes, agricultural residues, farm waste and other biodegradable waste streams. Biomass represents a continuously renewable potential source of methane and thus offers a partial solution to the eventual prospects of fossil fuel depletion. In addition, biomass can be economically converted to biogas at a variety of scales and thus can be tailored to supply local, regional and nationwide biogas needs.

Biogas is a product of bio-methanation process when fermentable organic materials such as kitchen wastes are subjected to anaerobic digestion in the presence of methanogenic bacteria [18]. Biogas mainly consists of methane and carbon dioxide together with smaller amounts of other gases and vapours, such as hydrogen, nitrogen and hydrogen sulphide (H₂S) [19]. The high concentration of methane makes biogas an attractive fuel and its use solves an emission problem since methane (as a greenhouse gas) is several times more harmful than CO₂ [20]. Biogas is about 20% lighter than air and has an ignition temperature in the range of 650°C to 750°C compared to diesel oil 350°C; petrol and propane of about 500°C; it is an odourless and colourless gas that burns with clear blue flame at a temperature of 870°C. Biogas is known by many names such as swamp gas, marsh gas, “will o´ the wisp” gobar gas [21].

Waste management is inadequate and ineffective in many urban and rural areas in Nigeria. The poor management of organic waste in Nigeria is a source of concern to the society. This waste poses a threat to urban management, defaces the aesthetics of the country’s cities through mounting heaps of solid wastes, and also a health hazard to citizens through the blockage of drainage systems, causing erosion and flooding. They are a breeding ground for mosquitoes, thus, posing a serious health risk to the Nigerian populace [22]. Nigeria generates more than 32 million tons of solid waste annually, out of which only 20-30% is collected and disposed in an open dump site [23]. Different researchers have reported that organic waste fraction of solid waste generated in Nigeria has the highest percentage which is over fifty percent [22]-[25]. Unfortunately, this portion of generated solid waste has not been properly...
enhanced for biogas production [16]. Large percentage of solid waste generated and dump indiscriminately in an open dump site can be useful to us if properly harnessed. One best method to achieve this is the adoption of the biogas technology.

II. MATERIALS AND METHOD

The materials used in this research are as follow:

- Water
- Water hyacinth
- Kitchen waste
- Mild steel bio-digester
- Pressure gauge
- pH meter
- Mercury in glass thermometer
- Scrubber
- Gas hose
- Storage gas bottle

The pH meter (Fig. 1) was used to monitor the pH of the system. To measure the pH of the slurry, the probe (glass electrode) is dipped into the sample of the collected slurry after each evacuation. The other part of the probe is connected to the analog pH meter.

![Fig. 1. Analog PH meter](image1)

The mercury in glass thermometer (Fig. 2) is connected to the digester. It was used to measure the slurry temperature.

![Fig. 2. Mercury in glass thermometer](image2)

The digester has a capacity of 0.030m³ and was fabricated using a mild steel material. A 30kg propane/butane gas storage cylinder was modified for the construction of the biogas anaerobic digester. The inlet valve for charging of slurry, thermometer for taking the temperature of the slurry, pressure gauge for taking the gas pressure, outlet valve for discharge of slurry, stirrer for continuous stirring of slurry, and gas discharging valve for evacuation of biogas were all connected to the digester (Fig. 3).

![Fig. 3. Fabricated Mild steel Bio-digester](image3)

The water hyacinths were collected from River Niger, Nigeria. The roots were properly removed and a grinding machine was used to grind it for the formation of slurry. The reason for grinding is to increase the surface area of contact for the microbial activity, so that biogas production would begin within the shortest possible time [5]. During the preparation of the feedstock, equal mass of kitchen wastes and water hyacinths were used. The water content for each sample was determined using the recommendations for better biogas production as established by Ebunilo, et al. [26]. This was the basis for the determination of the amount of water that was added for any given mass of total solid. Preparation of fermentation of slurry was by addition and vigorous mixing of total feedstock with an equivalent amount of water needed for maximum yield.

The mixture was introduced into the digester and observed for hydraulic retention time of thirty-seven days. The temperature and pH were monitored using mercury in glass thermometer and analogy pH meter respectively. The experiment was conducted within a pH range of 6.0-7.4 and mesophilic temperature range of 21°C-37°C.

III. RESULTS AND DISCUSSION

Due to maintenance, cost and technical know-how, a single batch AD reactor was used for this research work. Charging was done once and re-charging was only carry out
at the end of complete hydraulic retention time (HRT). This design is chosen for this study because it is suitable, cheap and can be easily constructed with minimal cost. The digester has an inlet through which the feedstock is fed. The digester has a mark to indicate the desirable level of feedstock while the remaining space is for gas production.

The amount of biogas produced was measured at interval intervals of four days after the first thirteen days using the displacement method. In other words, gas was released from the digester through the valve control into a 1000cm³ water level of the measuring cylinder. The measuring cylinder was then inverted with the gas pressure displacing equal amount of water and the readings were recorded. This procedure was repeated to ascertain the total volume of biogas produced. The volume of biogas produced was recorded as shown in Table 1. Fig. 4 shows the plot of volume of biogas yields against hydraulic retention time. The results obtained show that the hydraulic retention time was 37 days. That is, 24days of continuous biogas yields in interval of four days and the first 13days of anaerobic digestion without biogas yields. Minimum biogas yields were achieved on the 37th days. However, maximum biogas yield was obtained on the 25th day. The drop in production of biogas on 37th day was as result of completion of digestion. Also, the production rate was not uniform and this was as a result of variation in mesophilic temperature.

Fig. 5 shows the volume effect of pH, pressure, and temperature on biogas yields. According to Ebunilo et al., [26], optimum biogas yields are obtained within mesophilic temperature range of 36°C-37°C. A good look at Fig. 5 showed that better and improved biogas yields were obtained at an optimum mesophilic temperature range of 37°C. Therefore, the research work agrees with the work of Ebunilo et al. [26]. Furthermore, a better pH value and pressure readings were achieved at optimum mesophilic temperature, and this agrees with the work of Orhorhoro, et al. [27].

| TABLE I: THE ARRANGEMENT OF CHANNELS1 |
|-----------------|----------------|----------------|----------------|----------------|
| Number of Test  | HRT (Days) | pH | Temp. (°C) | Pres. (Bar) | Volume (cm³) |
| 1               | 13         | 6.0 | 35.00     | 0.75         | 7.8           |
| 2               | 17         | 6.8 | 34.24     | 0.86         | 6.0           |
| 3               | 21         | 6.9 | 36.24     | 0.64         | 6.9           |
| 4               | 25         | 7.1 | 37.00     | 1.00         | 9.5           |
| 5               | 29         | 7.2 | 29.25     | 0.91         | 7.6           |
| 6               | 33         | 7.4 | 33.00     | 0.52         | 6.9           |
| 7               | 37         | 7.4 | 21.00     | 0.50         | 4.5           |
| 8               | 40         | 7.4 | 15.00     | 0.50         | 3.5           |
| ∑               |            |    |           |              | 49.9          |

1Temp.-Temperature, *Pres.-Pressure, *HRT-Hydraulic retention time

IV. CONCLUSION

A Biogas was produced from a mixture of blended water hyacinth and kitchen wastes. As expected, optimal biogas production was found to be a function of temperature. Essentially, the standard rate digester was designed and fed with thick slurry and kept under standard atmospheric condition. The digester was allowed for 13 days to ascertain maximum rate of microbial activities and thereafter, tested for combustion and followed with measurement of the biogas produced. Significantly, biogas production was noted to increase with time. Specifically, the pressure of biogas after 13 days was 0.75bar. The highest pressure was found to be 1bar and that was day 25th day and the lowest was found to be 0.5bar which was on the 37th days.

The result of the research work shows a total of 0.0499m³ of biogas was generated. Therefore, kitchen wastes and waste hyacinth can be co-digested to produce biogas. With this technology, volume of waste generated in Nigeria can be managed and the energy generated can help in solving part of Nigeria energy crisis.

DOI: http://dx.doi.org/10.24018/ejers.2018.3.4.684
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