© 2018 IJSRST | Volume 4 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Anaerobic Digestion of Vegetable Waste In Lab-Scale Digester

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ABSTRACT

Biomass waste is a potential source of biogas production. A large amount of biomass waste is generated from agricultural process industries and vegetable market. In the present work a 25L of capacity single stage anaerobic digester has been designed and fabricated with its accessories. Cauliflower waste of1.3kg (dried in sunlight), 1.7kg of fresh cow dung, and 14L of water are used for anaerobic digestion process at mesophilic condition at 37^{0}C. Daily gas production rate has been measured for a period of 21 days. The total cumulative production of biogas is measured as 16.784L.

Keywords : Biomass Waste, Anaerobic Digestion, Gas Production.

I. INTRODUCTION

The biofuel is one of the options to fulfil the need as transport fuel. The second-generation fuels are suitable and viable alternative fuels for the internal combustion engines [1]. The alternative fuels are also classified as liquid fuel and gaseous fuel. The liquid fuels are biodiesel, methanol, ethanol, butanol, dimethyl ether, diethyl ether, bioethanol. And gaseous fuels are biogas, synthetic natural gas (SNG), hydrogen, synthetic natural gas (SNG), hydrogen emerged as possible alternative fuels [2]. Both of the fuels have certain advantages and dis-advantages. Alternative fuels obtained from biomass resources play an important role due to its abundant availability within India. It was reported that 200 million tons of biomass produce in India per year [3]. Biomass is a forest or organic waste, by product of crop production, agro or food industries waste, vegetable waste. There are so many biomass resources are available in India. They can be classified as there available in nature such as: grasses, woody plants, fruits, vegetables, manures and aquatic plants [4]. Crops are also used as a biomass like grain crops, grass crops etc. Biomass containing carbohydrates, proteins, fats, cellulose and hemicellulose can produce biogas. Agriculture residues are made from harvesting of agricultural crop. Biomass waste can also be generated from agro based industries, vegetable market, road sweeping etc. The excess food from hotel, restaurant, uneaten bread, rice, vegetables craps, nonstandard food are also used as a solid waste whereas the waste water containing like dissolved organic matter like sugar, starch etc. can be used as a biomass material. These types of wastes are anaerobically digested to produce biogas. The municipal solid waste can also be converted into biogas.

Biogas is produced from biomass by anaerobic digestion process within four steps hydrolysis, acidogenesis, acetogenesis, methanogenesis [5]. Raw biogas contain 50-70% methane, 30-50% carbon dioxide, the other gases like hydrogen sulphide, hydrogen, oxygen, nitrogen, carbon monoxide [6]. The composition of biogas is depending on several factor like temperature, pH value, loading rate etc. Mesophilic condition is the ideal condition for biogas production but the bacteria are more active in thermophilic condition and production of biogas is increased [7]. But there is a need of some energy consumption to maintain the high temperature. Hydrolysis and acidogenesis occurs efficiently at pH 5.5-6.5 and methanogenesis occurs efficiently at pH

6.5-8.5 [5]. The optimum range of pH is 6.8 to 7.2. [8]. The C/N ratio varies from 20-30 for optimum biogas production [9].

II. EXPERIMENTAL SET-UP

Anaerobic digestion is one of the process to convert the biomass or waste product into energy. Anaerobic digestion process happens in the absent of air. So for the digestion process a compact volume is needed which should be air tight. For the experiment a steel made 25 L of reactor has been designed for lab scale uses. A pressure gauge is attached at the top of the digester to measure the inside pressure of the digester. A heater along with thermostatic temperature controller is also attached for maintaining the constant temperature within the reactor. With the help of the temperature sensor the reactor performance can be observed at different temperature since it is one of the major operating parameter. A water jacket has been provided surrounding the reactor in which the heater is fitted to maintain almost constant temperature. A cylindrical batch type (stainless steel made) anaerobic digester of 25L capacity has been designed based on the literature review and fabricated for the experiment shown in figure 1.

Figure 1. Photographic view of the Digester

The photographic view of the experimental setup has been shown in Figure 1. The height of the digester is 77 cm from the ground level. The top of the lid of digester there is an inlet valve through which the feedstock is fed to the digester. A valve operated nozzle is used for collecting the gas generated in the digester. A ball valve is used in downward location of the digester to clean the digester after the experiment. A water displacement column of 45cm height and 9cmdiameter is used gas collection through gas nozzle. The digester is surrounded by a water jacket of capacity 15L. A 1000W thermostatic heater was used for heating the water within the water jacket. This water temperature is measured by a temperature indicator. A pressure gauge is attached at the top of the digester to measure the gas pressure inside the digester with a range of 0.1 kg/cm^2 to 0.5 kg/cm^2. The inlet and outlet feedstock valve are attached at the top and below the digester. A valve regulated nozzle is fitted at the top of the digester as a gas outlet. Water displacement method is used for measuring the daily gas production.

III. PREPARATION OF FEEDSTOCK

Cauliflower waste as a vegetable was collected from local market and cow dung was collected from a cow owner. The collected vegetable waste are dried in the sunlight for 7 to 8 days after cutting it into small spices about 10 to 15 mm size. After drying them in the sunlight the cauliflower waste has been grinded by a mixture grinder. Cauliflower waste (1.3kg), fresh cow dung (1.7kg) and water (14 L) were mixed properly and it has been observed that after absorbing the water the volume of the mixture increased by 2L. Hence the volume occupied by the feedstock becomes 19L. 25% of the total volume that is 6L (25% of 25L) was left for gas production. The analysis of the mixture done and pH of the mixture checked before poured it into the digester.

IV. DIGESTER PERFORMANCE

The production of biogas in the digester is measured regularly at 12.30 pm using a water displacement column which was shown in Fig. 1. The valve operated gas outlet nozzle was opened till the pressure in the pressure gauge becomes zero. Temperature of the digester is maintained at 37⁰C and the initial pH value is almost 7.

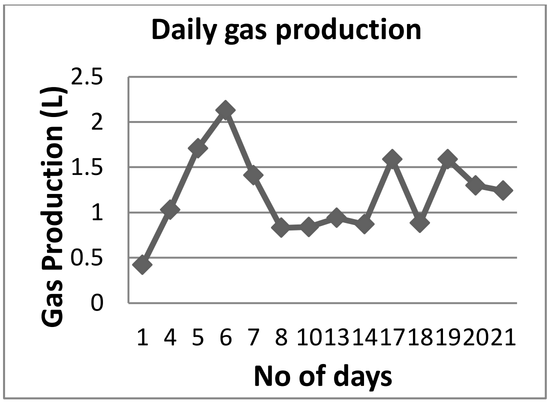

Figure 2. Daily gas production of the digester

It is observed from the fig. 2, that at the beginning of the digestion stage, production of carbon dioxide is more at the beginning of the stage and observed that produced has is not burnt. The first 2 to 3 days is considered as hydrolysis phase depending on the feedstock and after that acidogenesis stage when the accumulation of volatile fatty acid accumulated into the reactor. Hence the gas production is reduced later days. It was observed that after 8th no days, generation of gas production is slowly stabilized and on the 10th day the gas sample is burnt with a blue flame shown in fig. 3. So it can be considered that the production of methane was start from 8th day. It shows that the gas production is still continuing till 21 days of observation. The total cumulative biogas production is measured as 16.784L. It was observed that the pH value of the digested materials after 21 days is 4.73. Which indicate the digester becomes acidic that leads to lower production of biogas in later days. Daily pressure variation of the reactor was measured by pressure gauge is depicted in fig. 4. This observation of pressure variation is directly indicate the gas production rate at the digester.

Figure 3. Flame from digester gas outlet

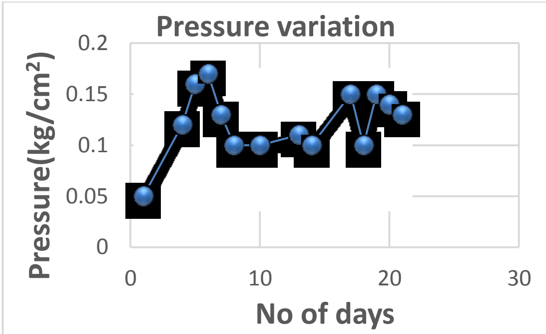

Figure 4. Variation of gas pressure with time

V. CONCLUSION

Performance of anaerobic digesters are dependent on number of factors such as feedstock quality, feedstock quantity, temperature, C/N ratio, pH value and type of digesters etc. A lab-scale batch type reactor has been designed for anaerobic digestion along with its accessories. Preparation of biomass feedstock from vegetable waste has been made to perform experimental analysis. Experiment study has been done using cauliflower waste in a single stage batch reactor with constant temperature of 37⁰C and pH value of 7. The cumulative biogas production obtained from this experiment is 16.784 L within the period of time 21 days. It was observed that the pH value of the digested materials after 21 days is 4.73. Which indicate the digester becomes acidic that leads to lower production of biogas in later days.

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