Bio-Gas Process Intensification

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ABSTRACT

Biogas is formed from anaerobic digestion of bio- logical wastes which is a renew-able energy resource. Typical biogas contains 50 - 60 % methane, 30-45 % Carbon dioxide, moisture and traces of hydrogen sulphide. Reducing the content of CO2 will significantly improve quality of biogas. Normally biogas usage is in the domestic way in the household way and upto certain level in the commercial level. In the field of biogas upgrading there are five convention technologies used for removal of CO2,this are commonly named as physical and chemical adsorption, membrane separation, cryogenic separation, chemical conversion method and pressure swing adsorption.

The biogas production is influenced by many factors Car- bon/Nitrogen Ratio, Temperature, pH Value, Loading Rate, Hydraulic Retention Time, Toxicity etc some other factor affecting the biogas production Agitation, additives and season effect. We are going to install the biogas plant setup and are willing to perform previous experimental achieved target for biogas setup earlier. To investigate effect of pressure on biogas production .We can use pressure swing adsorption to upgrading CH4 in biogas as anaerobic co-digestion process by using agricultural wastes. Biogas quality is increase by using low cost adsorbent.

In comparison with biogas and CNG, experimental reviews give idea about usage of biogas over CNG. Methane content is about 95% that can be used as fuel for vehicles, engines and gas turbines to produce electricity.

Keyword: - *Bio-gas up grade, Enhancement of Biogas, Carbon Dioxide removal, Pressure Swing Adsorption*

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1. INTRODUCTION

The biogas is a produced by the anaerobic decomposition of organic matter. It is primarily composed of methane and carbon dioxide with smaller amounts of hydrogen sulphide, ammonia and nitrogen. Usually, the mixed gas is saturated with water vapour. The low caloric value of biogas is due to the presence of the non-combustible CO_2 gas typically ranging from 25 to 50%.[1] Upgrading of biogas to higher CH_4 content through the removal of CO_2 and other components of the biogas would increase its caloric value. Theoretically more methane can be produced from lipids (1014 l/kg) compared to proteins (496 l/kg) or carbohydrates (415 l/kg)[2]. An increase of methane yields during co- digestion of sewage sludge and different types of lipid waste. Bio-methane has a methane content greater than 95% w/w typical of substitute natural gas or compressed natural gas[3]. Bio-methane can be used as fuel for stove/boilers, vehicles, engines and gas turbines to produce electricity, for the injection into the natural gas grid or for fuel cells[4].

In the process of biogas upgrading into biomethane the separation of minor impurities (H_2S, N_2, moisture etc) and especially CO_2 is necessary and crucial operation. Methods primarily used for CO_2 separation are able to some extent remove also minor compounds but in some cases there are installed special pretreatment units for removal of minor compounds [5]. Therefore configuration and presence of pretreatment operations derives from adopted method of CO_2 separation. Biogas can be upgraded for removing CO_2 by using technologies: pressure swing adsorption, chemical absorption, physical absorption, membranes separation and cryogenic separation [6].

The ratio of content carbon and nitrogen (C / N) of the raw material is essential in the production of biogas. The optimal C/N ratio is expected to be in the range 15 to 25 when the anaerobic digestion process is carried out in a single stage[7].Temperature choice and control are critical to the development of anaerobic digestion process, having a strong influence over the quality and quantity of biogas production. In the thermophilic range, high temperature causes higher rates of biochemical reactions and implicitly an increase in methane. The higher energetic consumption of the thermophilic process is offset by the higher productivity of biogas[8].The hydraulic retention time (HRT) small produce a good rate of the raw material flux, but reduced biogas productivity[9]. In anaerobic digestion all life processes are carried out at well-defined values of pH. If the pH value decreases below 6, methane production is strongly inhibited. Methanogenic bacteria require a pH value in between 6.5 to 8.0 [10].In Summer season there is higher production of biogas, while in winter season lower production [11].

A pressure swing adsorption plant consists of a series of vessels filled with adsorption material, working on 4 different phases: adsorption, depressuring, regeneration and pressure build-up [12]. The pressure is firstly reduced to atmospheric and then to a light vacuum. The vent from the first stage contains significant amounts of CH_4 and therefore it is sent back to the gas inlet, in order to keep the CH_4 losses low. To avoid the irreversible adsorption of the same in the adsorption material. Physical and chemical absorption instead of water organic solvents are used as absorption fluid [13]. Besides CO_2 also H_2S, NH_3 and H_2O can be separated. Chemical absorption: solvents as mono-ethanol amine (MEA) or di-methyl ethanol amine (DMEA) which react chemically with CO_2 are used. Amines are highly CO_2 selective, and result in minimal losses of CH_4, but they are toxic to humans and the environment and require significant energy consumption for regeneration.[14]. As in physical absorption, in chemical absorption regeneration always is carried out. The preliminary purification of the biogas is very demanding to avoid corrosion, undesirable chemical reactions and higher temperatures for the regeneration [15].

Membrane separation is based on the selective permeability property of membranes. Basic systems exist: gas-gas separation with a gas phase at both sides of the membrane and. Due to imperfect separation, multiple stages may be required [16].The cryogenic method of purification involves the separation of the gas mixtures by fractional condensations and distillations at low temperatures. The process has the advantage that it allows recovery of pure component in the form of a liquid, which can be transported conveniently [17]. Chemical conversion process is methanation, in which CO_2 and H_2 are catalytically converted to methane and water. Chemical conversion process is extremely expensive and is not warranted in most biogas applications. Due to highly exothermic nature of the methanation reactions, the removal of the heat from the methanator is a major concern in the process design [18].

2. EXPERIMENTAL SECTION

2.1 Bio-gas from cow dung

- To produce biogas from aerobatic digestion tank from kitchen waste which takes more time, due to which I have taken cow dung. We can also add kitchen waste in aerobatic digestion tank in future.
- To start with the experiment cow dung was added weighted 10 kg and mixed with 10 to 12 liter of water.
- The mixture was semi solid initially but was stirred by wooden rod through semi solid into thick liquid. The pH of this mixture initially 7.
- The tank was kept for 10 days for fermentation. After 10 days an observation the tank was lifted up that shows the gas is being produced.
- To study the gas, the match stick was lignite but it was lit-off.
- It was lifting gas so it means that CO_2 was being produced. So the CO_2 was removed from digestion tank funs completely so the digestion tank was initialized as it was before.
- After 10 days observation the gas was lignite again and the lit was light because so it means methane is in the biogas. The pH is 7 after observation.
- Gas sampling for further analysis

Fig. 1. biogas plant set up

2.2 Effect of pH

The pH-value is the measure of acidity/alkalinity of a solution (respectively of substrate mixture, in the case of AD) and is expressed in parts per million (ppm). The pH value of the AD substrate influences the growth of methanogenic microorganisms and affects the dissociation of some compounds of importance for the AD process (ammonia, sulphide, organic acids)[19].

When during anaerobic fermentation, micro-organisms require a natural or mildly alkaline environment for efficient gas production. An optimum biogas production is achieved when the pH value of input mixture in the digester is between 6.25 and 7.50. The pH value in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH value inside the digester can decrease below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria is very sensitive to pH value and do not thrive below a value of 6.5. Later, as the digestion process continues, concentration of NH_4 increases due to the digestion of N_2, which can increase the pH value to above 8 [20].

When the CH_4 production level is stabilized, the pH range remains between 7.2 and 8.2. During the period when ambient temperature varies between 22 and 26C, it takes approximately 6 days for pH value to acquire a stable value [31]. In the anaerobic digestion process, pH is a very important parameter. The effect of different pH on biogas production from food waste in an anaerobic batch reactor with a retention time of 30 days. The effect of pH on the biogas yield is experimentally analyzed in five laboratory-scale batch reactors maintained at pH 5, 6, 7, 8 and 9. The reactors were operated at mesophilic temperature condition with a hydraulic retention time of 30 days. The daily biogas production, cumulative biogas production, methane and carbon-di-oxide composition were measured. Biogas yield and degradation efficiency were substantially higher for the substrate of pH 7 compared to other pH values. The lowest biogas yield and degradation efficiency was obtained with the substrate of pH 5 [21].

That pH 7 made favorable condition for bacterial growth in the digester and produced better biogas yield compared to the others. Next to pH 7, pH 8 yielded better result followed by 6, 9 and 5. The degradation of TS, VS, and COD further support and strengthen the reported results [33]. The pH is a key parameter which informs about the smooth running of a biodigester, it conditions the activity of methanogenic microorganisms, the latter develop in a range of limited pH going from 6.5 to 8, with an optimal beach of 6.8 in 7.4, so a gap from the pH of this range can affect the activity of the methanogenic bacteria, which will have an impact on the production of biogas and which may even inhibit the anaerobic digestion process. It emerges essentially that the adjustment of the pH in a range going from 6.5 to 7,4 favors the development of methanogenic bacteria, what allows the increase of the production of biogas until 67 %, compared with the digestion without adjustment of pH[22].

Anaerobic treatment is a good choice to treat bioethanol waste due to the high concentration of COD content for producing biogas as renewable energy. In determination of optimum pH, bioethanol waste and rumen fluid fed into digesters with initial pH 6.0; 7.0 and 8.0. The initial pH 7.0 produced the most biogas with total biogas 3.81 mL/g COD. While initial pH 6 and pH 8 had total biogas 3.25 mL/g COD and 3.49 mL/g COD respectively. The optimum pH the higest biogas was pH 7. The controlled pH could increase total biogas formed . Urea addition could increase total biogas formed. The formed biogas was 52.47% greater than that of at without urea addition[23].

The effect of the initial pH on the anaerobic digestion of dairy waste. The biodegradability tests were carried out in a series of reactor of 500 mL of volume with four arrangements of the initial pH in mesophilic phase. After the incubation period (48 days), the height efficiency of removal COD was obtained for pH = 7, allowed by Reactor of pH=5.5, pH=9.5 and finally pH=4. The volatile solid, the removal efficiency was 62.51; 44.9; 43.8 and 25.82 % for pH= 5.5; 7; 9.5 and 4 respectively. The minimum production of biogas is very weak for the pH=4 and for the pH=5, 5. It is important for the pH=7 and the pH=9.5[24].

2.3 *Effect of pressure*

The pressure effects on the anaerobic digestion, in terms of pH-values, production kinetics and specific methane yields by batch experiments. For fermentation under no any additional pressure stress, the organic slurry has generated a very qualitative biogas that reached a methane content of 96.350 % in weigh, which is much above the average of 60% methane in biogas as defined in literature. The organic samples exposed at pressures of 2, 4 and 6 bar respectively, have generated biogas of a much lower quality, the hydrostatic pressure negatively influences the methanogenesis in anaerobic digesters [25].

It can be noticed that the methane content in biogas is significantly superior for the biomass sample exposed for anaerobic digestion in standard pressure of 0 bar, compared to other biomass samples which have been fermented under various hydrostatic pressure up to 6 bar. It is clearly proved that the samples conditioned for fermentation at pressures of 2, 4 and 6 bars have produced a definitely lower quality biogas, which confirms the theory that the hydrostatic pressure has an adversely negative influence on methanogenesis[26].

The production of biogas for combined heat and power generation represents a common method. The concept of pressurized two-stage anaerobic digestion integrates biogas production. The increasing solubility of CO_2 in process liquid at high pressures results in high methane contents in gaseous phase and in drop of pH. The effects of high initial pressures and dissolved CO_2 on pH-value, production kinetics and specific methane yields, pressurized batch methane reactors were built up, decrease in pH from 7 to 6.31[28].

As biogas is formed within anabolic digester tank, biogas decreases the rate of biogas production. When we write gas every day in the biogas tank, the average rate of gas was 3528 cm^3 per day while measuring gas every day. The biogas production rate was approximately 10167 cm^3 per day when we came out of daily biogas production in a biogas tank, when it came out to be expelled. Both of these data can say that when biogas is dropped out of the anabolic digester tank every day, biogas production rates are high.

2.4 PSA unit set up

- In our college there is only one bed type PSA unit. In that bed near about 500 gms of adsorbent can be added. Height of adsorbent bed is 13 cm and diameter is 5 cm.
- We are having activated carbon as an adsorbent and we have ordered Zeolite 13X and 5A adsorbent.
- In that case the adsorbent will adsorb CO_2 and in the outlet valve we will get the stream of methane gas.
- In PSA unit firstly we have opened the inlet valve and biogas has been added in bed and the pressure of the bed is increased. After some time inlet valve is closed and outlet valve is kept open.

Fig. 2. One bed PSA set up

- By reducing the pressure of the inlet of tank we will collect the CO_2 and the analysis of that CO_2 will be done.
- Compressor or high pressurized N_2 is used for increasing the pressure.
- But if we use compressor for increasing the pressure of adsorption bed at that time the possibility of reacting of air and methane is higher.
- So to neglect this problem of mixing of methane and air we use high Pressurized N_2.

Fig. 3. Adsorption bed

3. RESULTS AND DISCUSSION

- According to the literature survey the value of pH should be 6.5 to 8.2 so that the value of pH is 7. When one can produce maximum biogas.

- It can experiments setup the temperature was 28 C and pH of the setup is always 7.

- When the dung was used in the anabolic digester tank. The biogas formed after the first 10 days of the beginning, the amount of carbon dioxide is high, so it left the biogas out in the air and brought the anabolic digester tank to its original position. 20 days later, the biogas becomes in the anabolic digester tank, which has less carbon dioxide percentage. The production of biogas in the beginning is less.

- On 13 March 2018, 1.5 kg cow dung was added to the Digester tank. After observation gas production.

- Table 2 the biogas rate is biogas production rates in the anabolic digester Tank. It is added daily in biogas anabolic digester tank.

Date	Water column	Gas column	pressure of gas
6-2-18 (1 day)	70 cm	0 cm	0 N/m^3
16-2-18 (10 day)	62 cm	30 cm	3.38 N/m^3
16-2-18 (10 day)	70 cm	0 cm	0 N/m^3
26-2-18 (20 day)	65 cm	32 cm	3.6064 N/m^3
3-3-18 (25 day)	70 cm	35 cm	3.90 N/m^3

Table I: Observation Table of Pressure

Date	pH	Gas column	Gas production	Gas production rate
13/3/18	7	36 cm	52923.07 cm^3	-
14/3/18	7	39 cm	57333.32 cm^3	4410.256 cm^3/day
15/3/18	7	41 cm	60273.49 cm^3	2940.17 cm^3/day
16/3/18	7	43 cm	63213.66 cm^3	2940.17 cm^3/day
17/3/18	7	46 cm	67623.92 cm^3	4410.256 cm^3/day
19/3/18	7	48 cm	70564.09 cm^3	2940.17 cm^3/day

Table II: Observation Table of Gas Production

Date	Gas colum	Gas production per day
28/4/18	3.5 cm	5145.30 cm^3/day
29/4/18	8 cm	11760.68 cm^3/day
30/4/18	7 cm	10290.60 cm^3/day
1/5/18	8 cm	11760.68 cm^3/day
2/5/18	8 cm	11760.68 cm^3/day
3/5/18	7 cm	10290.60 cm^3/day

Table III: Observation Table of Gas Production per Day

Bed Height	13 cm
Bed Diameter	5 cm
Adsorbent	Activated Carbon
Adsorption Temperature	25
Adsorption Pressure	1 bar
Particles Diameter	.92 mm

TABLE IV: Observation Table of PSA Unit

3.1 Percentage of Methane Calculation

Methane percentage was determined using Gas Chromatography.

- Table 3 the biogas production rate when biogas is removed from anabolic digester tank every day.
- The biogas production rate is comparable in table 2 and 3, when biogas is removed daily from anabolic digester tank, the biogas production rate is high.
- Biogas is inserted into the PSA unit with a pipeline from the Anabolic Digester tank. The Activated carbon in the Adsorption bed was used as an adsorbent. Instead, it is possible to use different adsorbent such as Zeolite 13X, 5A, natural Zeolite, etc.
- In the Pressure Swing Unit, passing biogas on the 1 atmosphere, the carbon dioxide absorbed in biogas is absorbed. The biogas can be called upgrade biogas.

Fig. 4: Upgrade biogas flame

- Analyze the revised biogas and raw biogas both the gas was burned with flame. It burns with revised biogas flame and dark blue flame than raw biogas flame.

4. CONCLUSION

- When cow dung is use as a feed stock in biogas plant then it take 20 days to form biogas.
- In the biogas plant as the pressure increases at that time rate of biogas form per day decreases.
- At the time of making biogas, the amount of water in the aerobic digesters tank affects the biogas.
- When biogas is made from cow dung, it contains 68.25 percent of methane.
- When the pressure of biogas increases in the anabolic digester tank, the biogas production rate decreases. As the pressure decreases, the biogas production rate increases.

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