DETERMINATION AND OPTIMIZATION OF BIOMETHANE POTENTIAL OF ORGANIC SUBSTRATES USING ANAEROBIC DIGESTION

THESIS

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

ENVIRONMENTAL ENGINEERING

Under the supervision of

Dr. Ashish Kumar

(Professor)

By

Sachin Sharma

172756

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

MAY-2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled **"Determination and Optimization of Biomethane Potential of Organic Substrates Using Anaerobic Digestion"** submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Ashish Kumar** (Professor). This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Sachin Sharma

Roll Number – 172756

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, Solan

CERTIFICATE

This is certify that the work which is being presented in the project entitled **Determination and Optimization of Biomethane Potential of Organic Substrate Using Anaerobic Digestion** in partial fulfillment of the requirement for the thesis progress of Master of technology in Environment Engineering and submitted to Department of Civil Engineering of **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Sachin Sharma (172756)** under the supervision of **Dr Ashish Kumar,** Professor**,** Department of Civil Engineering , Jaypee University of Information Technology, Waknaghat .

Date: 6th May 2018

Dr Ashish Kumar **Prof. Dr Ashok Kumar Gupta** **External** Examiner

Professor Professor and Head

Department of Civil Engineering Department of Civil Engineering

JUIT, Waknaghat JUIT, Waknaghat

ACKNOWLEDGMENT

I take this opportunity to acknowledge all who has been great sense of support and inspiration throughout the project work. There are lots of people who inspired me and helped, worked for me in every possible way to provide the detail about various related topics, thus, making of report work success. My first gratitude goes to our head of department **Dr. Ashok Kumar Gupta** for his guidance, encouragement and support.

I am very grateful to **Dr. Ashish Kumar,** Professor, for all his diligence, guidance, and encouragement and helped throughout the project work. I also thank him for the time that he spared for me, from his extreme busy schedule. His insight and creative ideas are always the inspiration for me during the dissertation work.

Sachin Sharma

(172756)

TABLE OF CONTENTS

CONTENTS **Page no.**

3. EXPERIMENTAL SETUP AND METHOD

.

LIST OF TABLE

LIST OF FIGURE

LIST OF ACRONYMS AND ABBREVATIONS

FDT	Floating Dome Type
KVIC	Khadi and Village Industries Commession
ARTI	Appropriate Rural Technology Institute
NBMMP	National Biogas and Manure Management Programme
AD	Anaerobic Digestion
FW	Food Waste
CD	Cow Dung

Abstract

Absence of oxygen is one of the important factor in the digestion of organic materials occurs which generally results into generation of Biogas. Often this organic matter found in many wastes such as food waste, agricultural waste, and industrial waste. Biogas from these organic wastes are source of renewable energy. In this report, we are dealing with the anaerobic digestion of Cow dung and Food waste. Our main objective is to "Optimization and Determination" of Biomethane potential of the organic substrate by using anaerobic digestion as well as optimize the best ratio of cow dung and food waste. With the passage of time uses of anaerobic digestion is developing globally and resulting into various environmental and economic assistance to every developed and developing country. Today, in order to solve various problems or question related to the anaerobic digestion of organic waste various researchers are working in that direction. For this, we have study an experiment up to 45 days by the help of three digesters (D_1, D_2& D_3). During these days we performed some tests by taking a sample from each digester. i.e. pH, alkalinity, VS-TS,DO, BOD, Gas Measurement. By the help of these, we conclude that the digestion of food waste can be utilized to obtain biogas by mixing at the proper ratio. It can be utilized at the industrial level also. It's been reported that food waste digested with cow dung has maximum biomethane potential.

CHAPTER 1

INTRODUCTION

1.1 General

The requirement of the fossil fuel resources is increasing but the applicable resources are confined which can be fulfilled with the help of various renewable energy resources for the production of the energy required. The potential of renewable energy resources is momentous as the potential range of few technologies like wind energy, Biomass and hydropower is very high. The living matter available on the earth like trees, crops, algae and animal manure can give rise to biomass. Direct combustion of these materials has been used to produce biomass. The other method with more benefits can also be used for the production which is anaerobic digestion. Anaerobic digestion involves many complex interdependent sequential and parallel biological reactions. In these reactions of anaerobic digestion, the final product of one class of microorganism reacts as the substrate for the further reaction. These reactions finally give rise to a mixture of gasses known as biogas. This mixture mainly has methane, carbon dioxide, and nitrogen. The advantage of this method over other traditional methods is given below:

Advantages of Anaerobic Digestion:

- The organic loading can be reduced
- The purification can be achieved up to a very high rate
- The pollution rate is negligible

The discussed method completes in four phases which are given below

- Hydrolysis/liquefaction,
- Acidogenesis,
- Acetogenesis
- Methanogenesis

A. HYDROLYSIS

Generally feed provided to the micro-organism present in the form of various types of organic wastes. These waste materials generally consists of carbohydrates, fats, protein and lipids. These are degraded in to smaller molecules in process known as hydrolysis. So, hydrolysis the phenomenon in which bigger molecules are converting in to smaller molecules. Which can be seen for

Equation 1: Proteins + hydrolysis $\longrightarrow$ A soluble amino acids

Equation 2: Cellulose + hydrolysis $\longrightarrow$ A soluble sugars

Hydrolysis of cellulose (1.3): **$(C_6H_{12}O_6)$ n + H_2O ----- > $nC_6H_{12}O_6$**

B. ACIDOGENEIS

In the process of anaerobic digestion, after the hydrolysis acidogenesis is the second process which takes place. The molecules brake down in hydrolysis phases is further utilized by the microorganisms and further converted into smaller molecules i.e. various acids and gases such as CO_2 and H_2. This process can be seen in the equation shown below.

Equation 3: $C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$

Equation 4: $C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$

Equation 5: $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

C. ACETOGENESIS:

Now the by-products made in the acedogenesis phase is further utilized in the acetogenesis phase. During this phase there is a very important role of hydrogen gas. The process and by products of this equation can be seen in equations shown below:

$$\text{Equation 6: } C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$$

$$\text{Equation 7: } CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 2H_2 + H^+$$

D. METHANOGENESIS:

Once hydrolysis, acedogenesis and acetogenesis took place, methanogenesis is the last biochemical process which occurs. In order to get maximum yield of methane gas this process has a great significance.

The process to produce energy from biomass results in reduced volume with digested sludge which can be further utilized as fertilizer for agricultural fields. The fluctuations in price and uncertain supply of imported and conventional fields save foreign exchange benefits in the gross domestic product is also one of the advantages of this process. The obtained biogas from the biomass digestion can be utilized in different area like as cooking fuel, lightening fuel, incubators, radiant heaters, refrigeration, etc.

Biomass is mainly combustible gaswhich can be considered as a substitute for petroleum-based fuel and can be synthesized from biogenic sources. The biodiesel and organic production of the wastes of organic matter can also result in biogas. Carbon dioxide (CO_2) and Methane (CH_4) is the major components of biogas whereas a small amount of hydrogen (H_2) and hydrogen sulfide (H_2S) are also present in the biogas. The production of biogas gets highly affected by the pH, temperature, and concentration of the material mainly C/N ratio.Biogas gives rise to bioenergy which can be used as fuel. This energy i.e. bioenergy can be utilized in many places like in waste management to produceelectrical or mechanical power from the heat engine. Biogas is also helpful in restaurants and home for the cooking and heating purpose. Gas engines also utilize this biogas to convert gas into heats and electrical energy. So it can be said that the best way to manage organic waste is biogas.

The forms in which we can have biogas using different method are:

- The chemical reaction into landfill while the decomposition of organic waste gives landfill gas
- The digester at anaerobic conditions i.e. absence of oxygen produces digested gas.

1.2 Advantages and Disadvantages of Biogas

The biogas from biomass through anaerobic digestion has many advantages as well as a disadvantage as can participate in many productions whereas is less available. Few advantages and disadvantages are discussed below:

1.2.1 Advantages of Biogas:

- This technology is the most feasible and economical one to produce electricity and heat.
- It can give power in vehicles and can produce natural gas.
- The use of biogas in the industry is one of a chance of employment in a rural area for many people.
- Biogas is one of the viable energy sources which is helpful in the reduction of greenhouse effects as it is the non polluting and most clean source.
- As these plants are easy to set up at home so these need less capita investment.

1.2.2 Disadvantages of Biogas:

- The present technology requires large area if need to use at a large scale so it is less economical for that purpose.
- Biogas contains many impurities so cannot be purified completely which can give corrosion effect in an automobile engine.
- The biogas production is temperature dependent technique so in winters the amount of production is less comparatively.

1.3 Advantages of Biogas technology

- The fuel generated for the cooking purpose by this technology is very clean.
- Biogas plants can be directly connected to toilets for being used for sanitation purpose.
- The advanced biofertilizers can be produced from the biogas slurry through chemical manure.

1.4 Composition of Biogas:

The compositions of different components of biogas are given below in table 1. It is clear that in biogas there is methane and carbon dioxide present in large amount as compare to others whereas the oxygen is absent in this case. Some other gases are also there but in low amount.

Table 1.1: Composition of biogas

Compound	Formula	%
Methane	CH_4	50-75%
Carbon Dioxide	CO_2	25-50%
Nitrogen	N_2	0-10%
Hydrogen	H_2	0-1%
Hydrogen Sulphide	H_2S	0-3%
Oxygen	O_2	0-0%

.

1.5 Indian Scenario of Biogas

Biogas plants used for lightening and heating purpose are mainly synthesized from any type of food and dung of domestic animals. Organic matters like cow dung, waste from farms, kitchen and garden are used for the production of biogas for household purpose. Anaerobic digestion, a method to produce biogas, is one of the biological processes in which energy is generated by dynamic utilization of biogas (generally 20% carbon dioxide and 60% methane). The methane yield in biogas production depends mainly on the different biomass material being used. In 1939, S.V.Desai completed his experiment to produce biogas using an anaerobic method. The output of this experiment could be seen in 1951 in terms of advancement of the first biogas plant in India. That plant was named as KVIC digester plant i.e. the Gramalaxi plant of the KVIC. In rural India, biogas plants were first introduced to farmers by KVIC only. Their design becomes standardized in 1962. Later in 1978, the Janata biogas plant and in 1984 the Deenbandhu digester, developed by AFPRO became other two popular models [1]. The biogas plants based on organic waste like cattle dung was promoted later in India in 1981-82 using NBMMP. The main motto of this programme was to setup biogas plants to make organic fertilizers available to the farmer as well as plants for cooking purpose in the rural area. KVIC and state nodal departments/ agencies are the networks for the implementation of the programme. The monitoring of programme and selection of beneficiary is also carried by Panchayats. Along with that 13 biogas development and training, centers have also been setup to give training support. Later around 20,700 lakhs of biogas plants is setup in India in 2014-15 which is as much as 4 to 5% of LPG. For the future, it is being estimated that bio fuels can contribute 5000MW to overall renewable energy by 2022.

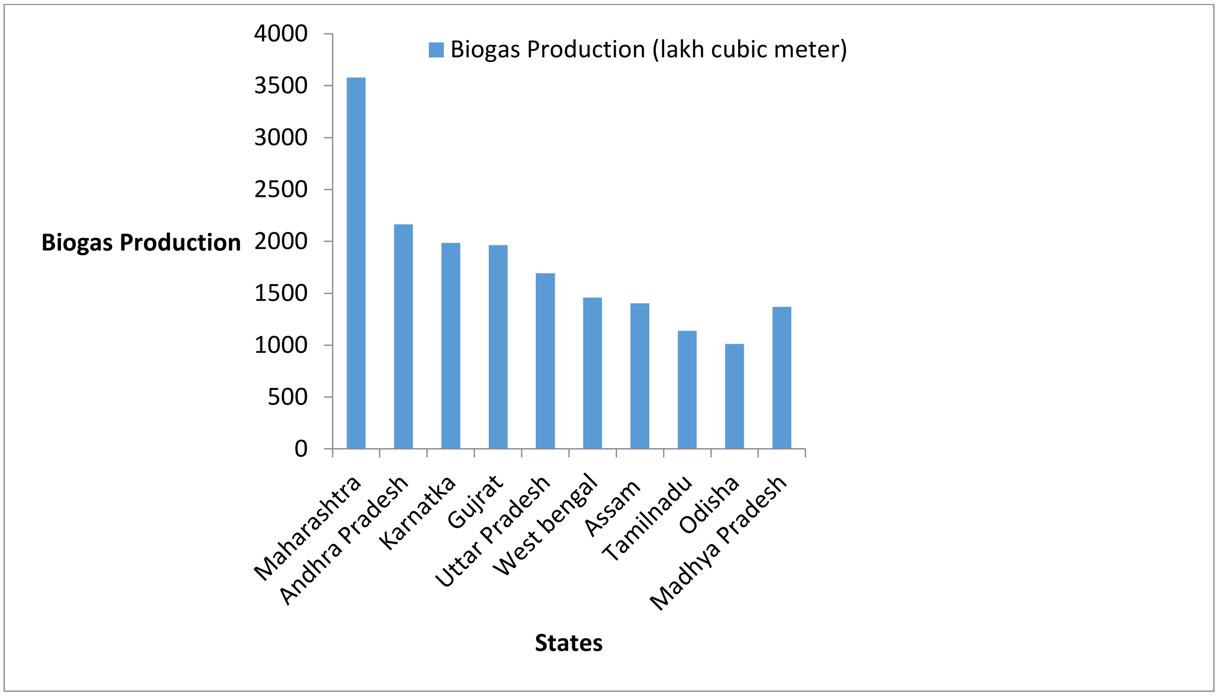

Figure 1.1: Production of Biogas in Lakh cubic Meter (2014-15) [1]

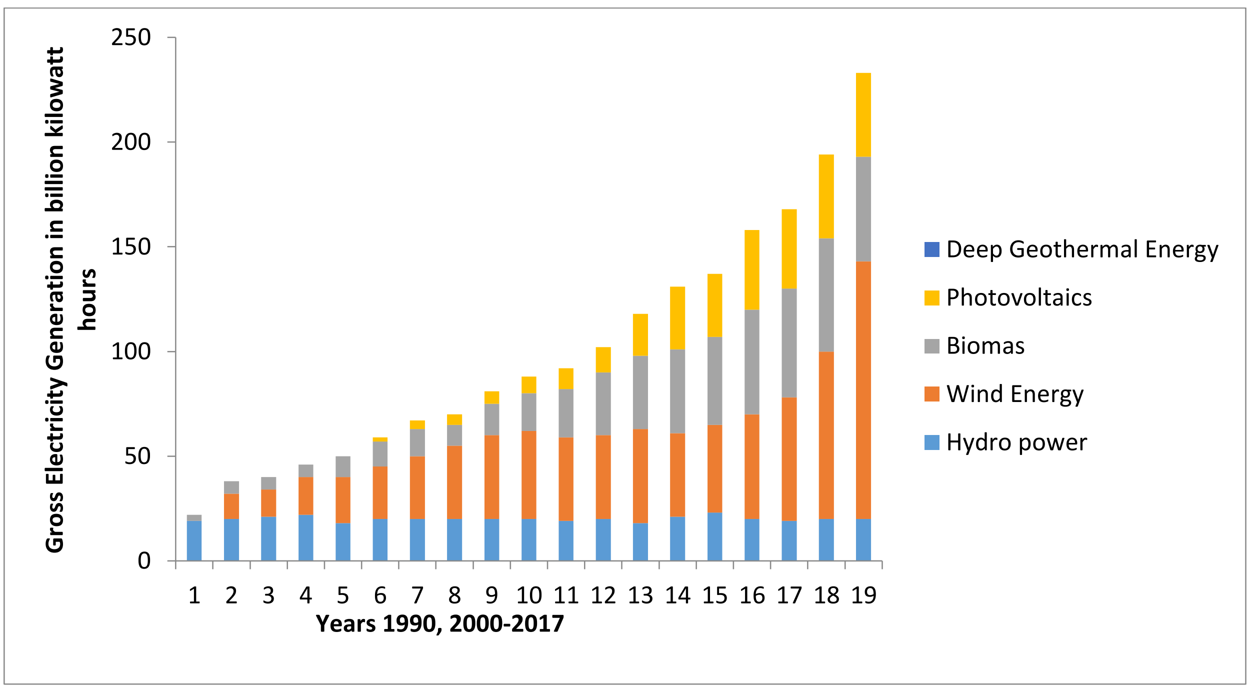

Figure 1.2: Production of Biogas in Lakh cubic Meter till 2017 [1].

1.6 Global Scenario of Biogas

As discussed the conventional source of energy is biogas which can be transformed into gaseous, solid and liquid fuels whenmatched to other energy cases. The fuelling in vehicles, heating and home electrification can be done using bioenergy. In 2012 in the worldwide around 2.6 billion population utilize biomaterials for needs which is 15% of energy consumption. The maximum consumption andproduction of fuels from biomaterials for transportationare by Brazil and the USA. Whereas the production of biofuels in America increased from 16 billion liters to 79 billion liters up to 2012.America and Europe use forest wastes to produce biogas for electricity utilization. They use mainly 71% of the biomass for electricity. In 2013 the electricity production from biomass was 462TWh. In Africa and Asia, most people lack access to electricity so biomass production is increasing.

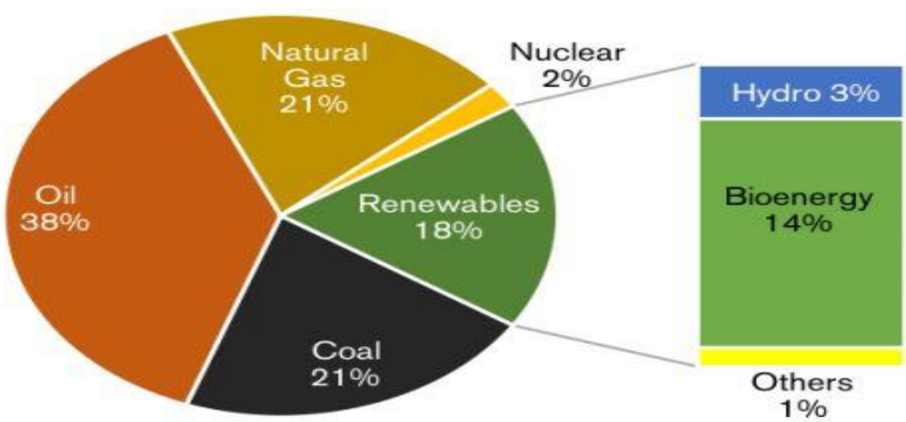

Figure 1.3: In 2013 Global energy consumption [3]

1.7 The current study is based on:

- This study includes determination of characteristics of substrate i.e. cow dungandfood waste
- To optimize the organic loading rate (OLR) of the optimized mixing ratio of co-digestion of cow dungand food waste.
- To optimize the mixing ratio of co-digestion of cow dungand food waste

Temperature for the processes to be done:-

- PsychrophilicTemperature (0- 25^{0}C)
- Mesophilic Temp (25-40^{0}C)
- Thermophilic Temp (40-60^{0}C)

Types of Reactor:-

- Batch Reactor
- Continuous Reactor

We are using a continuous reactor for this experiment.

The substrate to be used in this Process:-

We are using

- Cow Dung
- Food Waste

1.8 OBJECTIVES

1. To study the feasibility of co-digestion of cow dung and food wasteat psychrophilic temperature.
2. To optimize the mixing ratio of co-digestion of food waste and cow dung
3. To optimize the organic loading rate (OLR) of the optimized mixing ratio of co-digestion of cow dung andfood waste.

1.9 Future Scope

- It is a natural sources of energy production thus it becomes extinct day by day.
- Biomass does not emit any harmful gasses and produce clean energy.
- It helps to reduce the use of fossil fuel for energy production.
- The main reason behind the usage of biogas energy is that it can be produced from plants and animals waste which are again re used in energy production.
- It also helps to reduce the green houseemmission

CHAPTER 2

LITERATURE REVIEW

2.1 General

The experiment performed in this project is based on the biogas maximization and it includes some factors which related to objectives, other various literature. It include collection of data and materials based on the title of project, with the help of some journals, technical details and research papersthat is assembled by the organizations and government departments.

Our study is based on:

1. Characterization of materials used in experiment i.e. food waste and Animal manure.

2. Study on the basis of food waste and cow dung digestion.

Types of Biogas Plants used in India

Floating Dome Type

In India two types of FDT biogas plants are used at present:-

KVIC type biogas plant

Such type of design consist of a underground digester tank and having a gas holder. Some dimension of this tank is following:-

Depth	4-8 meters
Diameter	1.5-18 meters

When feeding is to be happen for tank the material is filled in mixing tank and attached directly to the underground tank. In this a slury pipe is attached with chamber.

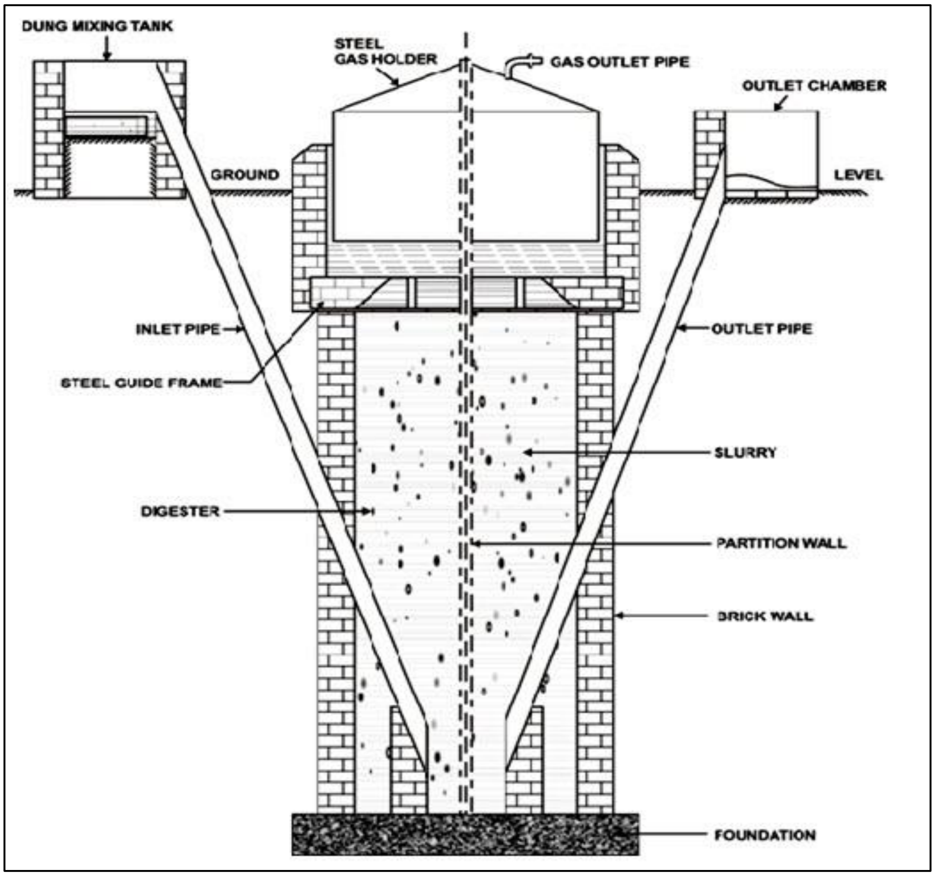

Figure 2.1 Design of KVIC type Biogas plant

ARTI (Appropriate Rural Technology Institute)

In Pune, Maharashtra an NGO has developed ARTI design. In this type of design gas holder is one third of digester. This plant is cost effective as compare to other biogas plant. Total estimated for the setup of this plant is one fourth of the construction cost of other plant.

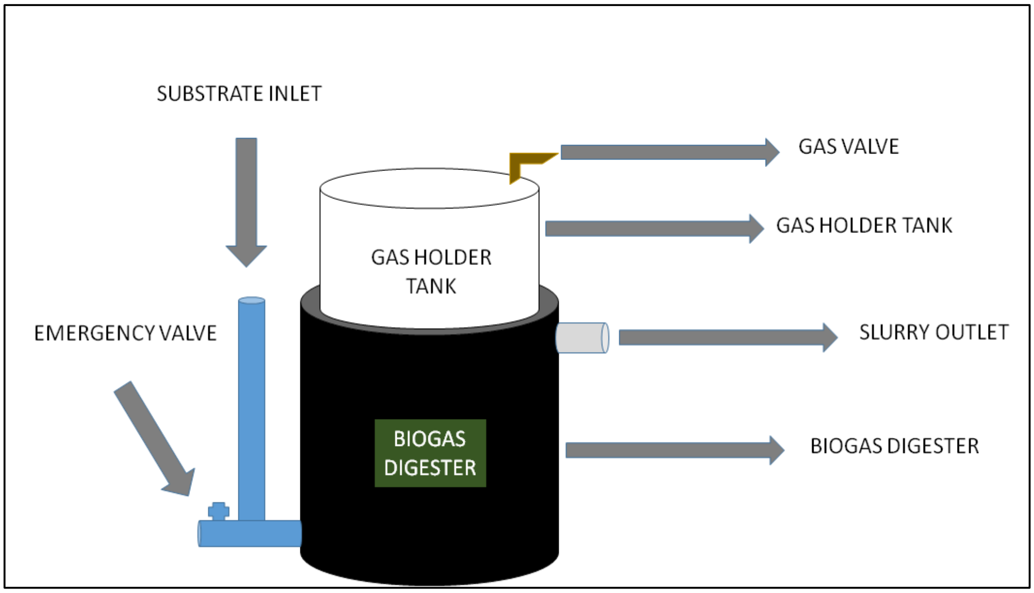

Figure 2.2 Design of ARTI TYPE Biogas plant

DEENBANDHU BIOGAS PLANT DESIGN:

This model was proposed by AFORO. It is hemispherical in shape and fixed under the ground level of earth. Material is feeded from inlet of pipe which is connected with mixing pit at ground level. A reinforced concrete dome is at bottom of plant's digester.

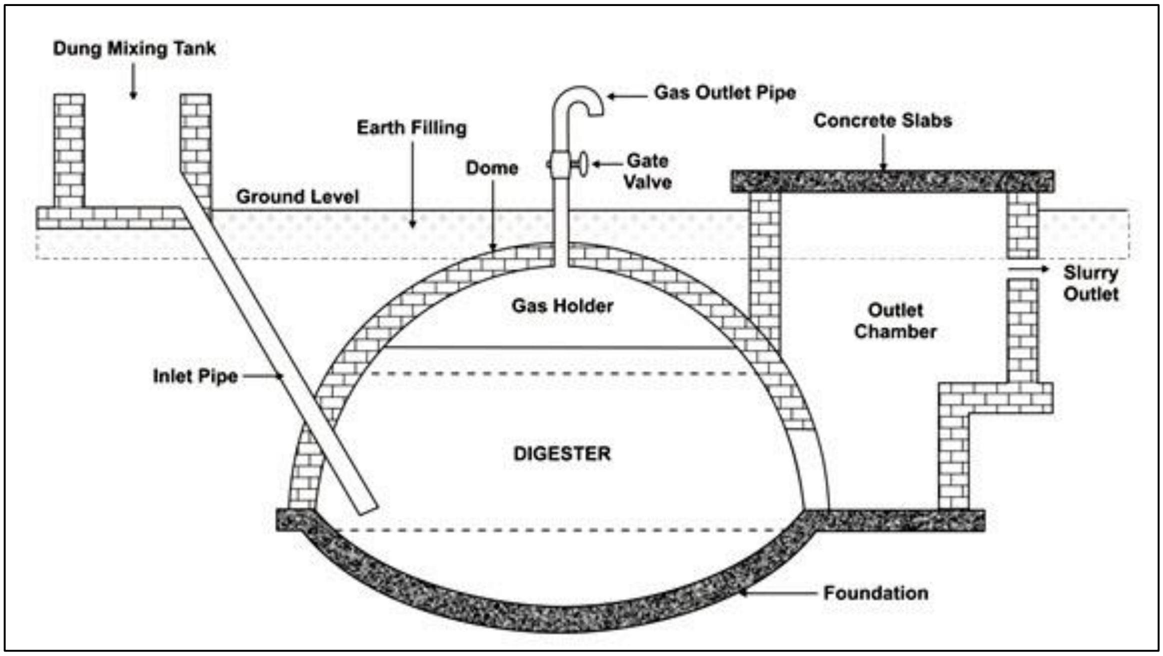

Figure 2.3 Design of Deenbandhu type biogas plant

SurajNegi et al. (2018)studied the co-digestion of rice straws and municipal solid waste. In their study they have taken different ration that is 1:1, 2:1, and 3:1 and calculated the variations in the methane generation rate constant and biomethanation potential. Their experimental results have shown the increase in biogas potential by 60% and methane potential by 57% in the case where the ratio was 2:1. They have got 0.1 d^{-1}value for constant k and 0.99 methane potential. They have found the maximum sludge activity i.e. 100% for the ratio 2:1. [2]

MuzammilAnjum et al. (2016)examined the effect of anaerobic co-digestion of catering waste with orange peel for the nutrient balancing. For the same study, they have taken the various ratios (from 20-50%) of orange peel with a constant amount of catering waste where the catering waste served as substrate. With this experiment, they have achieved the maximum degradation of about 49% with 50% of orange peel. The production of biogas was 89.61 m3 t-1 which was 1.5 times more than earlier. They mentioned the reason for these much better results was a dilution of inhibitory factors. So they concluded that the orange peel waste can be considered as a highly feasible co-substrate for anaerobic digestion. [3]

Musa B. et al. (2016) examinedthree different materials for the production of biogas as it is an alternative way to fuel.For this experiment, they have taken three materials with two different pH. The pH was pH1 = 7.08, pH2 = 7.32 for cow dung, pH1 = 5.49, pH2 = 5.26 for droppings and pH1 = 5.49 and pH2 = 5.75 for chicken droppings. Out f these three materials the maximum biogas was produced by chicken droppings followed by cow dung and minimum by droppings. The produced biogas had flammability order as cow dung > droppings > chicken droppings. So they concluded that cow dung can be considered as the best substrate to produce biogas as it has produced high-quality biogas. [4]

Beedu R et al. (2014) gone through the study of food waste for the production of biogas using anaerobic digestion. For the same study, they divided 80Kg cow dung into the batches of 10kg each and then mixed that into 10ml of water. Blue flame has given the indication of methane in a gas burner. The output of the experiments has shown a better result when the material was crushed as compared to uncrushed. The metabolism of gas can also get affected by underfeeding and overfeeding, one (underfeeding) will decrease the efficiency whereas other(overfeeding) can increase the pH. So they concluded that food waste can be considered as one of the effective replacement of LPG. [5]

Deressa L et al. (2015)worked on the vegetable waste mixed with the cow manure and fruit waste for the production of biogas. For this purpose, they have used papaya, mango, banana peel, cow manure, and avocado. The production of biogas from vegetable and fruit waste has taken 55 days. The maintenance of pH near 6.7-7.4 was necessary as it is sensitive towards pH. They concluded that the reduction in TS/VS has increased the production [6].

Wang X et al. (2014)studied the changes in the dairy waste, rice straws and chicken manure due to the change in carbon-nitrogen ratio and temperature. By conducting an experiment they have found that rate and methane potential is changing in a different manner. With the increase in temperature,the rate is decreasing while methane potential is increasing. Along with this, the methane potential was increased with the increase in carbon-nitrogen ratio as the bad effect of ammonia has decreased [7].

Andrea Hublin et al. (2014)studied the agro-industrial waste under anaerobic digestion for the production of biogas. The prime focus of the author was to utilize the easily available plants. Using this idea the author and coworkers have produced maximum power i.e. 2160000kWh y^{-1} and heat of about 2400000 kWh y^{-1} along with the 2500kg of methane [8].

Maryam M. Kabir et al. (2014)investigated the anaerobic digestion on forest waste after adding organic solvents like ethanol, ethanol and acetic acid in that for the production of biogas. For that, they have started pretreatment with keeping the 50% solvent in waste at 190o for 60min. The results they got from this trial was 50% more than the production from untreated one. The exact amount of methane they got is 0.23 and 0.34 m3 CH4/kg VS [9].

B. M. Hanafiet. al. (2013) studied the kitchen waste for the production of biogas. The increases amount of waste in a country has given a vision to the author to utilize the waste for the production of energy which can be a step for betterment. For the same studied they have collected waste from the two areas i.e. Chittagong and Bangladesh. The total waste they have collected was approx. 80 to 85 MT organic wastes from kitchen waste in Chittagong which has resulted into 5100 to 5300 m^3biogas potential. After achieving the best results they have concluded that it can be a way to reduce pollution and increase environment betterment [10].

Dioha I.J et al. (2013)have examined the different parameters like pH, temperature, carbon to nitrogen ratio, concentration and solid waste for the biogas production. For the different parameters, they have set up different ways. The optimum range of C:N ratio which can regulate the pH of slurry is 25-30. As a result, they got that carbon to nitrogen ratio has a major effect on the production amount [11].

Bhatti et al. (2017) has worked in Srinagar, Kashmir, India. Due to low temperature range, Srinagar is not favourable for the growth of anaerobic bacteria. They used MATLAB 2014a for detailed analysis. Optimisation of mass flow rate of the slurry for an N- flat plate collector for winter season has been performed. They stated that biogas is one of the feasible form of renewable energy. Solar energy plays a vital role in the formation of biogas. India is a developing country, big fraction of the population in rural areas where electricity is major issue. Biogas can be utilised by the people living in rural areas. The maximum temperature in Kashmir has been reported around 23 degree Celsius. With the help of model they were able to maintain 32-37 °C within the digester for months of February to October, which is optimum for the growth of anaerobic bacteria in order to generate methane gas.

Devi R. et al. (2016) has setup an experimental setup and determined suitability and potential of the Pine needles as substrate for biogas. They have prepared two experimental named as Digester-1 and Digester-2. In Digester-1, cow dung has fed as substrate whereas in in Digester-2 a mixture of cow dung and Pine Needles has fed as a substrate. For both of the digesters inoculum was made of cow dung only. Both the Digesters has been compared for physicochemical various properties like pH, temperature, TS, VS, biogas production etc. The retention time for both of the Digester was 70 days. Digester-1 and Digester-2 has generated biogas 2.47 litre and 5.30 lit respectively. Based on the biogas generation they have concluded that Pine Needles is comparatively better substrate. Based on the experiments performed on Digester-1 and Digester-2, they have also stated that Pine Needles has more calorific valve and cellulose fraction than that of cow dung.

Tripathi K. A et al. (2015) done a work on generation of Biogas in a hilly terrain. Pine Needle has been used as co-substrate in Biogas Plant installed in Jaypee University of Information Technology, Waknaghat, solan India. They have stated that although biogas technology is already implemented in Himachal Pradesh but it has various limitation. One of the biggest limitation of Biogas plant in Himachal Pradesh is very low temperature in winter season, moreover temperature in summer season is not appropriate enough to generate good amount of Bio gas. They have concluded that Pine Needles (mixed with sewage water) may a good alternative for feed in digester, since it has 55% cellulose fraction. During summer (March-April) highest amount of biogas generation was 7.3 lit/day, where as in winter season the highest amount of biogas generation was only 1.4 lit/day. They have reported approximately 64% reduction in the Volatile Solids in the months of March-April.

Beedu R. et al. (2014) has concluded that food waste can be uses as substrate in biogas generation. India is such a country which mostly does not rely on other countries for food, where crude oil is imported. So, we have plenty of food, hence the wastage is significant. They have stated that if we could use food waste generated by local residential areas, cafeterias, restaurants, hotels, markets and canteen and utilize it for bio gas generation, it will not only save money spend in LPG cylinders but also solve environmental pollution problem up to some extent. They have prepared food waste based biogas generation system. They have also prepared a design and fabrication and cost analysis between LPG cylinders and biogas, moreover they have elaborated its working principle. Overfeeding and underfeeding both may result to various problems in biogas plant, overfeeding may result into rise in pH whereas underfeeding may affect the efficiency of the plant in terms of microbes development. A biogas plant can recover its installation cost within 2-3 years.

Vaid V. et al. (2013) has asserted that biogas is an inexhaustible sources of energy which primarily consist of methane (55%). It is a viable way to deal with food waste. Biogas neither have any geographical barrier nor it needs and advanced technology in order to generate biogas but its true potential is yet to be explored. When it is compared with wood, kerosene, LPG and other non-renewable energy sources, biogas is a very cheap and can save money up to a great extent. It is reported that recent biogas system (kitchen waste as feed) is 800 time more competent than conventional biogas system. In a survey conducted by Vaid V. et al. (2013) Delhi Technical University produces 300-400 kg of food waste daily. They have concluded that if they install biogas plant for the food waste produce they can save up to 50% gas expenditure moreover can provide worthwhile amount of manure for gardening purposes in the campus.

Agrahari P.R. (2013) conducted a study in the month of January-February (2012) in order to determine that whether kitchen waste can be utilized for bio gas production or not. In this study greenhouse canopy has been used in order to raise the temperature for the better yield of biogas. The observations has been done for 30 days. Biogas yield has been reported significantly low in winter season. Since temperature plays an important role, greenhouse canopy can be used in order to raise the temperature of the digester. They have also reported that though life of aluminium digester is less because it can easily be disintegrated by bacteria but it is a better substitute for the betterment of environment. In order to raise its life it is tank is coated with black paint. They have stated that when aaluminium tank is used in place of plastic tank it affected the yield of biogas in positively, since absorption rate for aluminium is high. A digester of 1000 kg can produce enough yield in order to accomplish the cooking requirement of a family (4-6 members). Total methane volume for the digester placed in ambient temperature was 0.1483 cum whereas it is 0.195 cum for the digester placed in green house chamber.

Somashekar K. R. et al. (2013) has evaluated biogas yield from food (rice, vegetable peeling, and cucumber) waste. A 20 L anaerobic digester (prepared in lab) has been used for the biogas production. The detention time of the digester was 60 days, production of the gas was reported on 16th day. The total amount of gas generated in 60 days was 68.85 lit. Model prepared by the Somashekar K. R. et al. (2013) was very similar to the UASB, the only difference was feeding was done from the above. From the study they have concluded that food waste is appropriate for the biogas production. The ratio of food waste to waste was 1:1. The weirdest part was biogas was generated on 16th day but gas did not burn till 23rd day. The pH of cow dung slurry, fresh food slurry, fresh cow dung + Fresh food slurry and digested slurry was reported 6.6, 6.1, 6.35 and 7.1 respectively. Whereas TS of cow dung slurry, fresh food slurry, fresh cow dung + Fresh food slurry and digested slurry was reported 8.5%, 9.3%, 8.9%, 5.34% respectively. VS of cow dung slurry, fresh food slurry, fresh cow dung + Fresh food slurry and digested slurry was reported 93.1%, 94.9%, 93.7%, 81.66% respectively. Phosphate (mg/100g) of cow dung slurry, fresh food slurry, fresh cow dung + Fresh food slurry and digested slurry was reported 0.26, 0.3062, 0.28, and 1.027 respectively. of cow dung slurry, fresh food slurry, fresh cow dung + Fresh food slurry and digested slurry was reported. Ambient temperature was always found greater than that of temperature inside the digester.

Riar et al. (2013) N. asserted that fraction of kitchen waste in MSW is significant. Instead on disposing it on landfill site, we should think of its treatability at personal level. Anaerobic digestion proc (approximately 27,000 INR) less can be used in order to treat the kitchen waste. Bio gas plants are such economical that it can recover its price within 2-2.5 years. Such plants can be installed in 424sq ft. plant fabricated by Deenbandhu biogas plant can yield up to 6 cum which can readily serve 8-12 hours for 10-14 people. Biogas yield primarily depends upon pH, TS%, and temperature which is found 7, 12% and 37 degree Celsius respectively.

Horvath et al. (2016) asserted that today and in future, one of the gigantic problems is emission of those gases which are responsible for global warming i.e. primarily CO_2. In order to tackle with this problem we've to curtail emission of CO_2. The biggest source of CO_2fossil fuels. So, we've to look for renewable energy sources as bioenergy. The massive advantage of adopting bioenergy over fossil fuel is that it helps in fighting with problem of organic waste and bed odour and unhygienic condition caused by it as well. In the last decade a great work has been done in the field of *lignocellulosic* biomass, progress in *high rate system* and *membrane technology* with in the anaerobic digester. Since there is a massive demand of renewable energy so we need to look for new sources of renewable energy and different substrate and new amendments in recent biogas technology in order to make present process much cheap and efficient, although for better efficiency, we need sustainable *pre-treatment technologies*. The SRT and HRT of the tank must be designed such that it does not cause wash out of microorganisms, UASBR is one its example. In any case if sludge granulation hampers or blocks, it must be sent back to digester with the help of provision of membrane technology.

CHAPTER 3

EXPERIMENTAL SETUP AND METHODS

3.1 GENERAL

For the completion of project work to fulfil our objectives which are the utilization of waste material for the biogas, some experiments were carried out which have been discussed in the present chapter. A lot of tests were carried out before and after the completion of digestion for charactering the Physiochemical properties of material. A continuous measure of methane production and biogas amount was also taken care and results were recorded properly. To check the results of different digesters a batches of tests were carried out. For aim to be completed some of the samples were kept in incubator, so temperature was maintained constant were as continues measurement of pH was done. On the other hand some other materials were examined at ambient temperature. The sensor was used to measure the amount of methane and biogas was examined by the water displacement method. The more details of the complete experiment has been discussed following.

3.2 DETAILS AND SOURCE OF SUBSTRATES

The present aim concentrates on the different waste materials like cow dung, pin needle and food waste for the production of biogas using anaerobic digestion. The substrate for the aimed project was collected according to their ease of convenience. The mess of the university was one of the main part as we got the waste food.

3.2.1. Food waste

As obvious the food in the hostel mess can never get utilized completed, a very less amount of food always get wasted. Taking care of this factor we have visited our hostel mess for continuous six days for different food waste. As a waste we have got some fruit peels, chapattis, rice and some vegetables etc. The daily collected waste were kept in bags and stored in the refrigerator in fluvial hydraulics lab in the civil department for maintaining the quality of that till the time of use. After the completion of process of collecting food for six days, the food was grounded to the fine particle in mixture grinder. The fine particle obtained has small size and large accessible surface area so give higher amount of biogas. Then the required ration of food was utilized for the different set of experiments.

3.2.2. Cow Dung

The cow dung which was being used as another material was collected from the villages near the university campus. This material was also kept in refrigerator for maintaining it for longer time. The material was being used in different amount at different time to check the variation of the output with the input. In the present study I have taken small amount of dung first and then increased the amount to the large scale so the results were different from the previous experiment in which I has taken the large amount of input all together. After completing this experiment one more experiment was carried out in which the mixture of cow dung and food waste was utilized together for the same aim. This material has resulted in good amount of methane and biogas which can be considered due to the potassium, nitrogen enrich property of material. Also the easily availability of the substrate makes it better option. So we can say that the material is one of the effective material for our objective.

3.3 SUBSTRATE CHARACTERISTICS TO BE DETERMINED

Before the final step, we must know the potential using various physicochemical test of the material being used. For the same purpose different tests were carried out in different designs. Mainly two designs were planned out of which one was to check the temperature, carbon to nitrogen ratio, TS, VS, TOC, alkalinity pH and COD whereas the other design was planned to check the BOD, pH and alkalinity. These steps in the present work helped to determine the various in different substrate and given idea of the best substrate which can be used in future for more production.

The three different digestion steps were taken in which the ratios of the substrate were different. The three ratios of the three different setup is given below. Three digesters D1, D2 and D3 are used respectively.

- D_1 :- 25% Cow Dung & 75% Food Waste

- D_2 :- 75% Cow Dung & 25% Food waste
- D_3 :- 50% Cow Dung & 50% Food Waste

Figure3.1 Digester 1(25% CD & 75% FW)

Figure 3.2 Digester 2 (75% CD & 25% FW)

Figure 3.3 Digester 3(50% CD & 50% FW)

3.4Tests to be performed on samples (done)

3.4.1 pH test

Basically pH is used to identify the acidic or basic character of solution. Solution having pH less than 7 is termed as acid or having pH greater than is known as base. Solution having pH 7 is known to neutral.

pH meter is used for measuring the pH of digesters.

Figure 3.4 Measuring pH of sample

3.4.2 Alkalinity test:

It is the chemical ability of solution to neutralized acid. It is also known as water buffering capacity or have ability to resist pH. For checking the alkalinity of the material used we have followed the given procedure.

Procedure

INLET

1. Different Conical flasks were used with 100ml sample in each flasks.
2. The first step was taken to remove chlorine from the solution using sodium thiosulphate solution of 0.1N. For this one drop of the thiosulphate was added to the solution.
3. After that phenolphthalein indicator was added (just two drops). The addition of indicator changed the colour of solution to pink. Than the solution was being titrated with 0.02N H_2SO_4till colouless solution was achieved.
4. The volume of $H_2SO_4$was being noted down.

OUTLET

5. The solution is then mixed with another indicator i.e. methyl orange which turned the sample yellow.
6. The solution is than titrated with 0.02N H_2SO_4till the colour become pink.
7. The volume of$H_2SO_4$was being noted down.
8. The alkalinity was than calculated using formula given below.

$$\frac{V * Normalityofsulphuricacid * 1000 * 500}{volumeofsample}$$

Figure 3.5 Performing alkalinity of sample

3.4.3 Temperature:

Temperature is one the important parameter in the production. So continuous measurement of temperature was done. In general we can check the temperature daily using the normal glass thermometer. But for our experiment we have used digital thermometer for the temperature.

4.4.4 Determination of Total solids, fixed solids and Volatile solids:

Total Solids: It is total amount of solid present in the water sample.

Fixed Solids: These are also considered as inorganic matter.

Volatile Solids: Those solids present in the solution which get removed or lost on ignition of 550^0C.

Procedure

1. First of all the three separate dishes were used with 20ml samples in each dishes. The samples weight were noted down.
2. The samples were kept in the oven at 105˚C for the removal of the liquid material.
3. After 24 hours the samples were taken out from the oven and weight were examined once again to check he variation.
4. Then muffle furnace was used to heat the sample once again at larger temperature i.e. 600˚C for two hours.
5. After the heat treatment fixed solid samples free from volatile samples were achieved. The weight of the final collected samples were noted down.

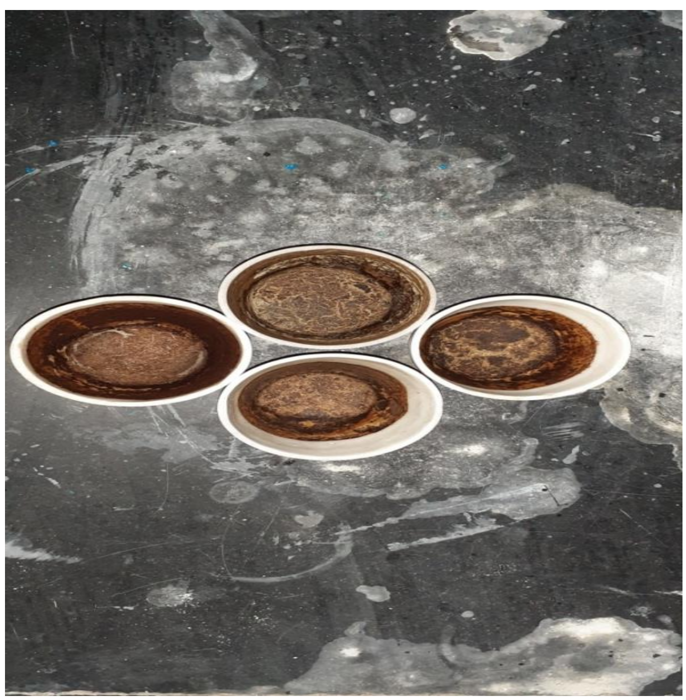

Figure3.6 Oven dried sample for total solid determination

3.4.5 Total Organic Carbon Estimation:

The total amount of carbon materials like bicarbonate, carbonic acids and carbon dioxides have been checked. For estimating these materials the following procedure has been followed.

Procedure

1. The different samples of about 1g each has taken from digester and kept to dry at 100°C for 15-20 minutes in oven.
2. The weight of dried samples were checked which was 0.05g and then put it in flask of 250ml capacity.
3. 1N 10ml of $K_2CrO_7$was added to the flask.
4. To the solution mixture 20ml of H_2SO_4 were added with continuous stirring up to 60 minutes.
5. The flask were kept at room temperature to cool down naturally.
6. Then the mixture was diluted with the 200ml of distilled water.
7. To the prepared mixture 10 drops of diphenylamine, 0.2g sodium fluoride and 10ml Phosphoric acid were added with continuous mixing.
8. The above mixture was then titrated with 0.5N ferrous ammonium sulfate which has given turbid blue colour to the solution.
9. The blank sample was prepared in the same manner.

4.4.6 BOD_5

The BOD_5 of the material was examined using following procedure.

Procedure

1. The sample of about 2ml was taken and diluted in 398ml of distilled water.
2. The diluted solution was then transferred to BOD bottles.
3. The DO meter was used to check the amount of dissolved oxygen. The check value was noted down.
4. Then the BOD bottles were kept in incubators at 20°C for 5 days.
5. The amount of dissolved oxygen was again checked after 5 days with the same DO meter.

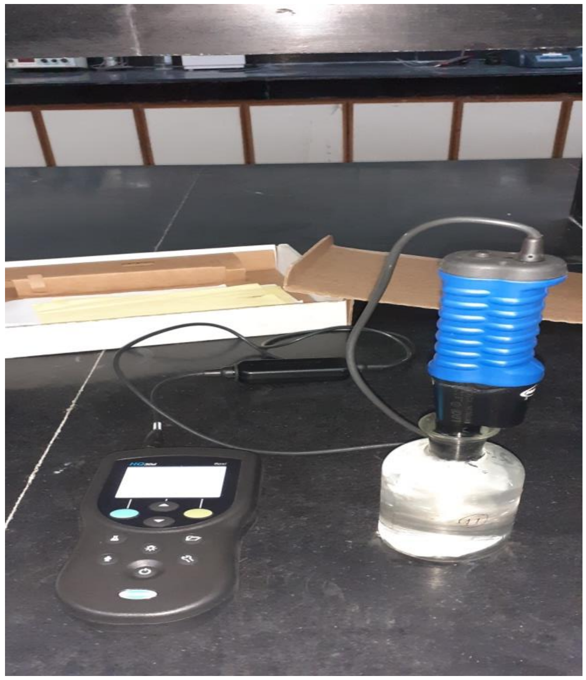

Figure 3.7 Testing DO of sample

VOLATILE FATTY ACID (VFA)

The VFA tests can be used for alkalinity measurements. The measurement of VFA was done using Kapps method. The complete procedure is being discussed below.

Procedure

1. The filtration of solution needs to be done before analysing the VFA. For the filtration blotting paper, 1 µm and 0.45µm membrane filter was used.
2. This solution was transferred to titration vessel of about 25ml.
3. The pH of the solution was also recorded initially.
4. The pH of the solution was maintained at 5.0 by titrating the solution with 0.1N sulphuric acid. The volume(X1) of the added was noted.
5. Then the pH is again changed to 4.3 by adding more sulphuric acid to it and the added volume (X2) was again noted down.
6. Again next volume(X3) is noted when pH was reached to pH 4.

7. The complete steps were performed continuously to ignore exchange between atmosphere and solution.

Calculation scheme according to Kapps:

Alk = A * N * 1000/SV

Alk = Alkalinity [mg/l], also referred to as TIC (Total Inorganic Carbon).

X= Consumption of Sulphuric acid (H_2SO_4, 0.1N) to titrate from initial pH to pH 4.3 [ml].

X= X1 + X2 [ml]. N = Normality [mg/l].

SV = Initial sample volume [ml].

VFA = (131340 * N * B/ 20) – (3.08 * Alk) – 10.9

VFA = Volatile fatty acids [mg/l acetic acid equivalents].

N = Normality [mmol/l]

B = Consumption of sulphuric acid (H_2SO_4, 0.1N) to titrate sample from pH 5.0 to pH 4.0 [ml], due to HCO_3/CO_2 buffer. B = A2 + A3 [ml]

SV = Initial sample volume [ml]

Alk = Alkalinity [mg/l]

Chapter 5

Results and discussion

General

This chapter discuss the result obtained during the optimization of mixing ratio and organic loading rate. Further this process discuss various chemical characteristics of the anaerobic digestion process which were analyzed during experiments. The characteristics are given beow:

5.1 pH: - ThepH is one of the very fundamental indicator of the stability of the anaerobic digestion process. The pH can range less than 7 or greater than 7. pH has a great importance during the methanogenesis process. If pH is not in the defined range during the digestion process methangenesis process may not work efficiently. Further, pH is a basic indicator which tells that whether there is an gathering of volatile fatty acids or not in the digestion process. If the VFA gathering is there automatically the pH of the process will gradually or suddenly drops down and and hence process stops. In additions,it helps us to know about the behavior of our experiment either it is acidic or basic. This we have to check pH of digester regularly.Optimum range of pH for this experiment is 6.5 – 7.5.The experiments of the pH was conducted time to time. It was decided to perform pH whenever there was a feeding. Before the next feeding used to done, a sample was taken of the outlet of the each digester and pH was used to check. During the experiments it was found that most significantly the pH of each of the digester was found within the range. Generally, from the literature it is advisable that the pH of the anaerobic digestion process should be kept in the range of 6.5-7.5. If the pH of the digester will not be kept within the provided range the process may lead to inefficient yield of biogas or it may also be possible that the process inhibits. Henceforth, it is required to maintain the pH of the digester within the suggested range. . Which can be seen in the figure below.

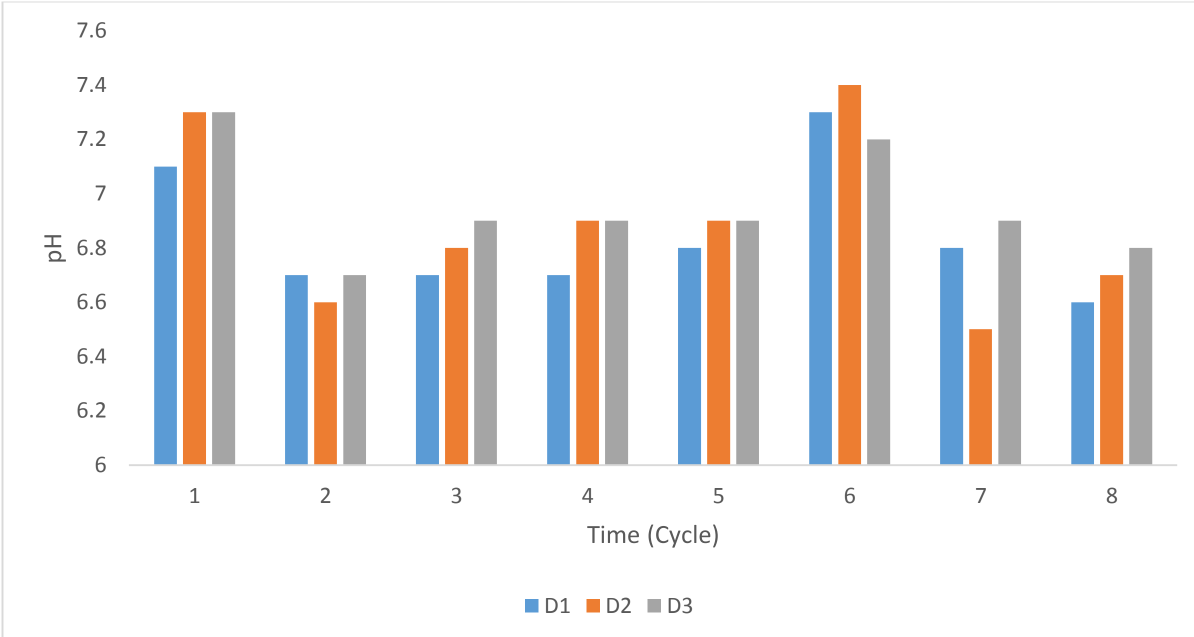

Figure 5.1 pH of inlet/outlet samples

Alkalinity: -After the pH, alkalinity is also one of the very fundamental measure in order to knowIt is the chemical ability of solution to nuterlised acid. It also known as water buffering capacity or have the acidity or basicity of the anaerobic digestion process. Generally, during the anaerobic digestion process there are four process which takes place i.e. hydrolysis, acedogenesis, acetogenesis and methanogenesis. So, during the acedogenesis phase if generation of acids takes place, there should be sufficient alkalinity present in the system which can neutralize the acidity produced during the acedogenesis phases. Basically, alkalinity is nothing but the buffer capacity of any process which takes care of the acids produced during any biochemical process. Hence, it is very important to monitor the alkalinity of the digestion process. During the experiments it was found that in all the digester the alkalinity was found in a sufficient manner. Generally alkalinity of the digester was reported within the range of 1000-3000 mg/l.

Volatile Fatty Acid (VFA):- After pH and alkalinity, volatile fatty acids are among the one of the important parameters of the digestion process. As the name suggest volatile fatty acids are nothing but kind of acids produced during the anaerobic digestion process. The generation of volatile fatty acids are quite normal process but however there for a stable anaerobic digestion process it is not recommended that VFA should increases.

Interestingly, if the concentration of volatile fatty acids increases it may lead to accumulation of acids in the system and hence drops down the pH of the whole process. Knowing the fact that methanogeneses are the microorganisms which works in a certain pH range only. Generally from the past studies it is noticed that for an efficient anaerobic digestion process generally a pH range of 6.5-7.5 is recommended. However the best yield of biogas can be seen of a pH of 7.0. Hence, monitoring of VFA becomes necessary during every anaerobic digestion process. In this study also, monitoring of the volatile fatty acids has been done. Most of the time in every cycle the volatile fatty acids were found within the desirable range.

VFA/ Alkalinity ratio: In addition, in order to analyse or examine the stability of the anaerobic digester the ratio ofVFA to alkalinity is determined. Generally this ratio varies >0 to any value. However, various literature suggests that for a stable anaerobic digestion process a VFA/alkalinity ratio of less that 0.8 is recommended. In this study also a VFA/alkalinity ratio is determined for all the digesters and cycles. From the results during the experiments it was found that all the digesters were running at the VFA/alkalinity of les that 0.8. However in few last cycles of the digesters it was noticed that this ratio was approaching 0.8 and possibly if further an increment in the organic loading rate was done then there is a possibility of this ratio will exceed 0.8 for few digesters. Which can be seen in the figure below.

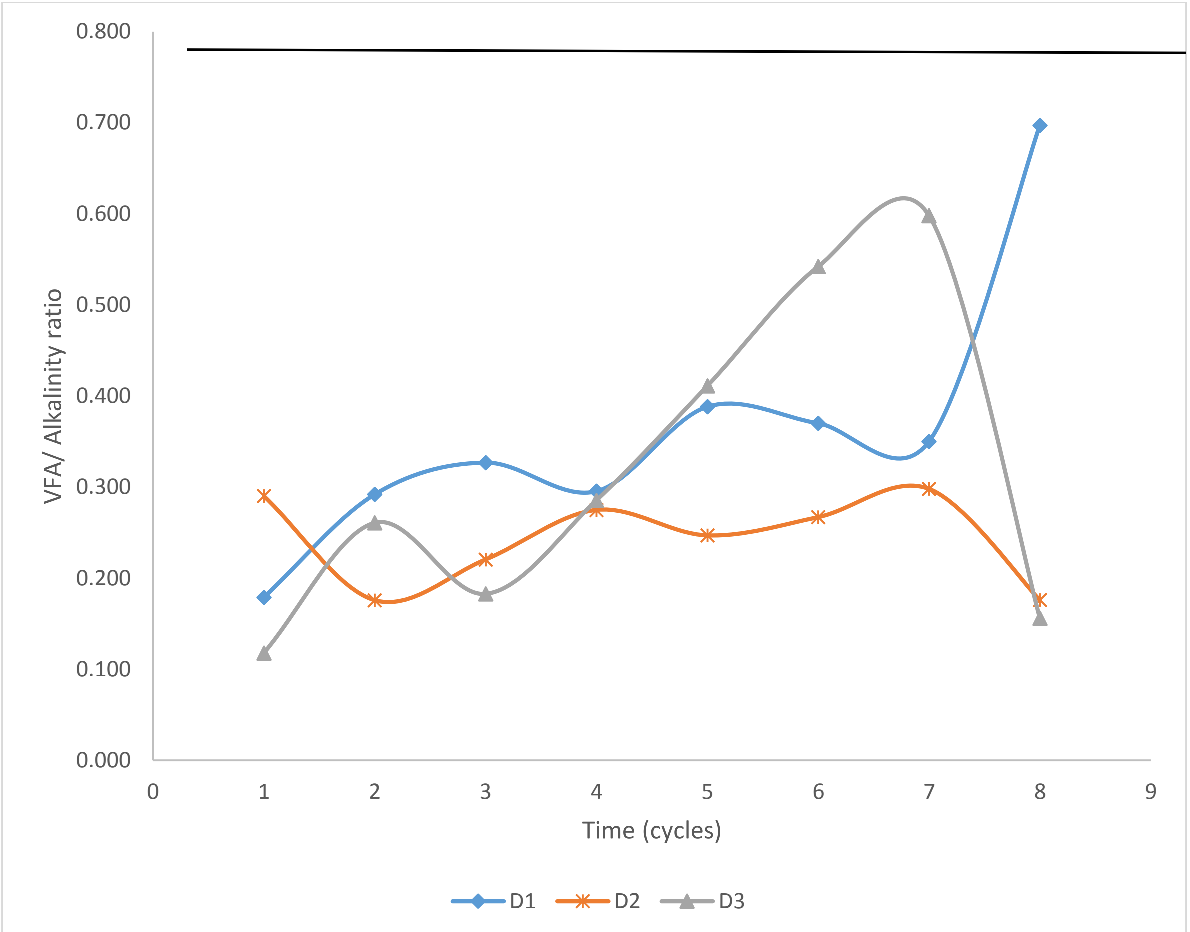

Figure 5.2 VFA/Alkalinity Ratio

Temperature: -Temperature is a vital parameter in any anaerobic digestion process. In addition performance of any anaerobic digestion process has great dependency on temperature. In this experiment the digestion was performed at 25°C.During the experiment we have fixed temperature condition by the help of AC in lab. In this experiment digital thermometer is used.

Determination of Total solids, fixed solids, and Volatile solids: -This test is performed to know about the amount of organic consumed by the bacteria.The significance of VS,TS and FS is inlet and out is different. In Inlet the significance of the these parameters is that it tells us the organic content in the feed and on the other hand when we take sample from the outlet and analyse it for these test the reduction of VS,TS when compared to the inlet or feed tells us the organic content utilized with in the digestion process or by the microorganisms. Which can be seen in the figure below.

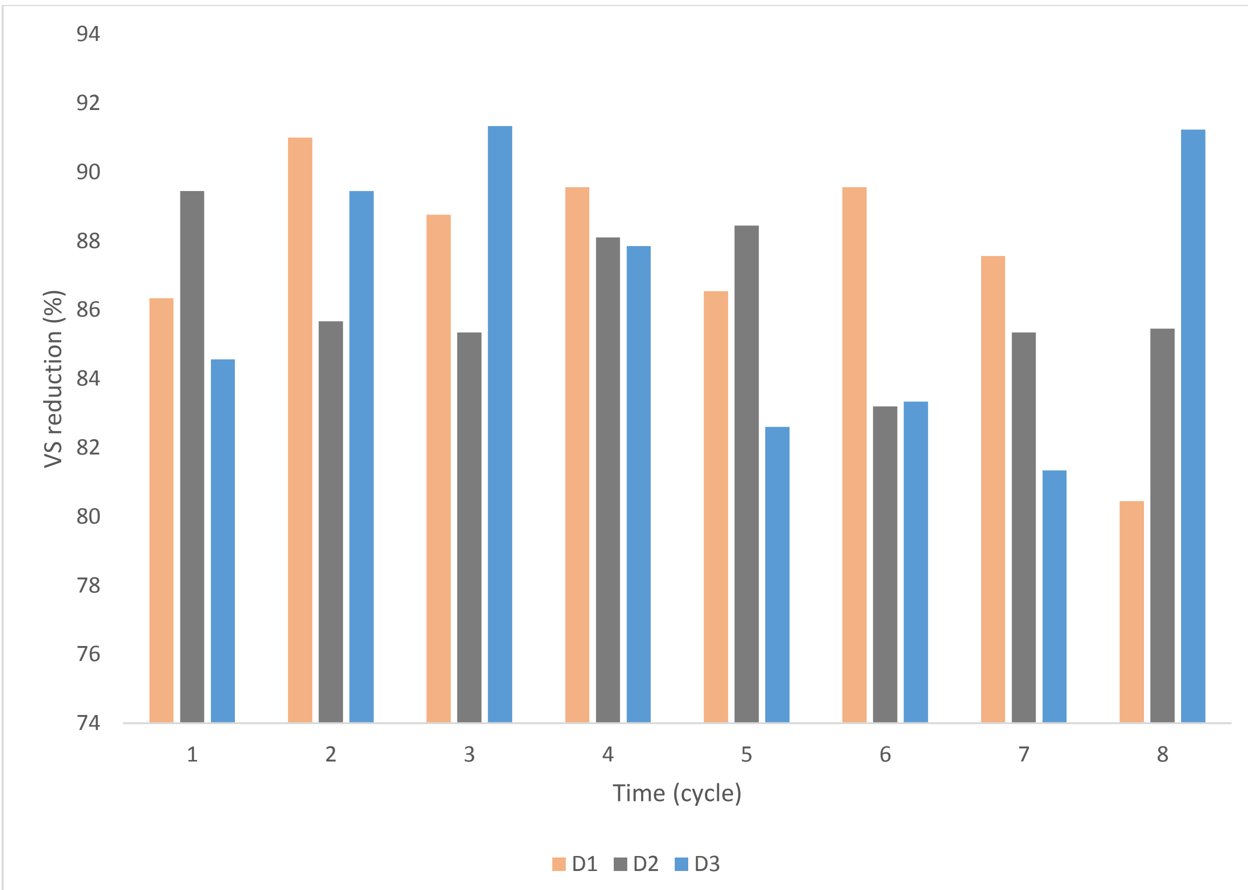

Figure 5.3 VS Reduction

BOD_5:-BOD_5 isone of the most important test during the anaerobic digestion process. At any time t this parameter signifies about the organic matter present in the digestion process.Hence, it is very important to analyse the BOD_5regularly. In this study also the determination of $BOD_5$was done. The samples was taken at the time of feeding and from outlets. The reduction of the BOD_5during the experiments was reported in the range of 40-60%. Which can be seen in the figure below.

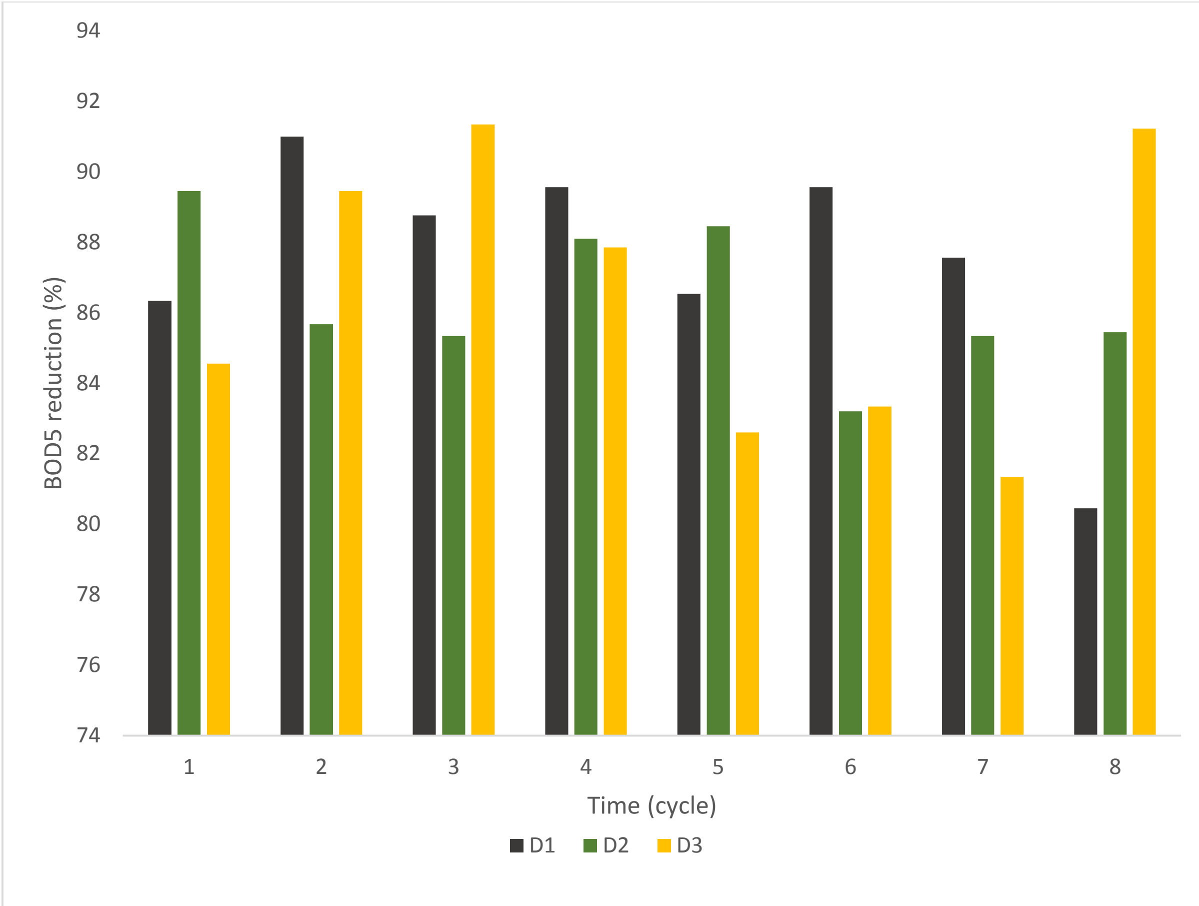

Figure 5.4 BOD_5 Reduction

Biogas generation during each cycle

During the experiments a regular monitoring of the biogas generation was done. Which can be seen in the figure below. Form the fig it can be seen that as we increased the organic loading rate the biogas generation increased accordingly. The one of the objectives of the study was to optimize the mixing ratio of the food waste and the cow dung and moreover the organic loading rate. From the cycle no. 8 it can be seen that D2 and D3 are working proper at 0.55 gmVS/L/day. However, the performance D1 was not fount suitable. The digester with mixing ratio 50-50% cow dung and food waste respectively shows the best biogas generation.

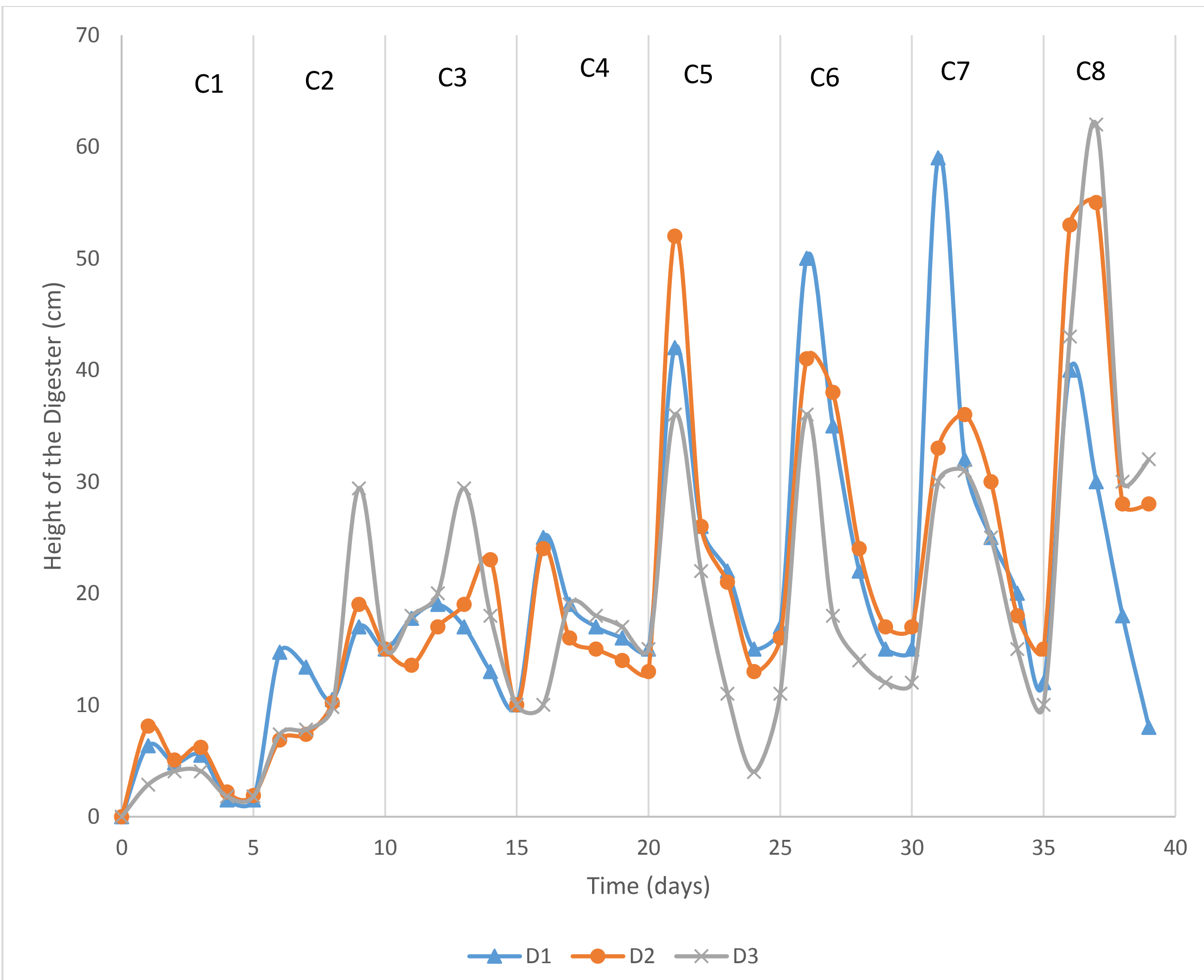

Figure 5.5 Daily Biogas generation

Conclusion

From the experiments performed it can be concluded that food waste and cow dung are one of the good source of organic content. They both are rich in biodegradables and nutrients. Further, it is concluded that bot the substrates can be utilized in anaerobic digestion process. Even at low temperature i.e. 25℃, digestion of both the substrates were performed very well. However, due lack of time the optimum organic loading rate cannot be concluded and at this stage with the help of experiments obtained in 8 cycles it can be concluded that Digester-2 and Digester-3 can yield biogas however Digester-3 has yielded more biogas when compared to Digester-2. Moreover, it is expected that Digester-1 will be able to yield biogas if further increase in OLR is done. In addition, the study concludes that the best mixing rate is found 50-50% food waste and cow dung respectively. The study conducted will be very usefull for the people living in area were the average temperature is 25℃.

References

1. Singh, K. J., Sooch, S. S.; "Comparative study of economics of different models of family size biogas plants for state of Punjab, India"; Energy Conversion and Management; 2004; Vol.45; pp.1329-1341; DOI : 10.1016/j.enconman.2003.09.018
2. SurajNegi, HiyaDhar, AtharHussain, Sunil Kumar; "Biomethanation potential for co-digestion of municipal solid waste and rice straw: A batch study"; Bioresource Technology; Volume 254; April 2018, Pages 139-144; https://doi.org/10.1016/j.biortech.2018.01.070.
3. Muzammil Anjum, Azeem Khalid, Samia Qadeer, Rashid Miandad; "Synergistic effect of co-digestion to enhance anaerobic degradation of catering waste and orange peel for biogas production"; SAGE journal; Volume 35; July 2017; Page no. 1-11; https://doi.org/10.1177/0734242X17715904.
4. Musa, B. and Raji, H.M; "Quantitative and Qualitative Analysis of Biogas Produces From Three Organic Wastes"; INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH; Volume 6; March 2016; 299-305.
5. RajendraBeedu and Pratik Modi; "Design of Bio Gas Generation Plant Based on Food Waste"; International Journal of Current Engineering and Technology; February 2014; 417-420;DOI: http://dx.doi.org/10.14741/ijcet/spl.2.2014.77.
6. LetaDeressa, Solomon Libsu, R. B. Chavan, Daniel Manaye, AnbessaDabassa; "Production of Biogas from Fruit and Vegetable Wastes Mixed with Different Wastes"; Environment and Ecology Research; volume 3; 2015; 65-71; DOI: 10.13189/eer.2015.030303.
7. Wang, X., Lu, X., Li, F., & Yang, G.; " Effects of Temperature and Carbon-Nitrogen (C/N) Ratio on the Performance of Anaerobic Co-Digestion of Dairy Manure, Chicken Manure and Rice Straw: Focusing on Ammonia Inhibition"; PLoS ONE; May 2014; Volume 9, e97265.doi:10.1371/journal.pone.0097265.
8. Andrea Hublin, Daniel Rolph Schneider, JankoDžodan; "Utilization of biogas produced by anaerobic digestion of agro-industrial waste: Energy, economic and environmental effects"; Research gate; Volume 7; June 2014; 626-633; DOI: 10.1177/0734242X14539789.
9. Kabir, M. M., Rajendran, K., Taherzadeh, M. J., &SárváriHorváth, I.; "Experimental and economical evaluation of bioconversion of forest residues to biogas using organosolvpretreatment"; BioresourceTechnology;Volume178, July 2014; 201–208; doi:10.1016/j.biortech.2014.07.064.

10. B. M. Hanafi, L. Bhattacharjee, S. M. R. Rahman and M. A. Basit; "APPLICATION OF KITCHEN WASTE IN BIOGAS SYSTEM: A SOLUTION FOR SOLID WASTE MANAGEMENT IN CHITTAGONG"; Proceedings of 3rd International Conference on Advances in Civil Engineering; December 2016.
11. I. J. Dioha, C.H. Ikeme, T. Nafi'u, N. I. Soba and Yusuf M.B.S.; "EFFECT OF CARBON TO NITROGEN RATIO ON BIOGAS PRODUCTION"; International Research Journal of Natural Sciences; Volume 1; September 2013; 1-10.
12. Bhattacharya, S.K.; Madura, R.L.; Walling, D.A.; Farrell, J.B. Volatile solids reduction in two-phase and conventional anaerobic sludge digestion. *Water Res.* **1996**, *30*, 1041–1048.
13. KUMAR, A., Devi, R. and Kumar, S., 2016. Use of pine needles as substrate for biogas production. *International Journal of Renewable Energy Research (IJRER)*, *6*(4), pp.1242-1247.
14. Tripathi, A.K., Kumari, M., Kumar, A. and Kumar, S., 2015. Generation of biogas using pine needles as substrate in domestic biogas plant. *International Journal of Renewable Energy Research (IJRER)*, *5*(3), pp.716-721.
15. Beedu, R. and Modi, P., 2014. Design of Bio Gas Generation Plant Based on Food Waste. *International Journal of Current Engineering and Technology*, p.417.
16. Vaid, K., Macovei, A. and Tuteja, N., 2013. Knights in action: lectin receptor-like kinases in plant development and stress responses. *Molecular plant*, *6*(5), pp.1405-1418.
17. Ravi P. Agrahari, G. N. Tiwari, 2013,"The Production of Biogas Using Kitchen Waste",International Journal of Energy Science, 3(6), pp.408-415.
18. Somashekar, R.K. and Prakash, K.L., 2013. Spatio-temporal variation of heavy metals in Cauvery River basin. *Proceedings of the International Academy of Ecology and Environmental Sciences*, *3*(1), pp.59-75.
19. Forsgren, K.L., Riar, N. and Schlenk, D., 2013. The effects of the pyrethroid insecticide, bifenthrin, on steroid hormone levels and gonadal development of steelhead (Oncorhynchus mykiss) under hypersaline conditions. *General and comparative endocrinology*, *186*, pp.101-107.
20. Horváth, I.S., Tabatabaei, M., Karimi, K. and Kumar, R., 2016. Recent updates on biogas production-a review. *Biofuel Res. J*, *10*, pp.394-402.