ESTIMATION OF BIOGAS POTENTIAL OF THE FOOD WASTE GENERATED IN A HOSTEL MESS

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by

Pravin Kumar
111BT0570

Under the Supervision of

Prof. P. Balasubramanian

Department of Biotechnology and Medical Engineering

National Institute of Technology, Rourkela

Rourkela, Odisha – 769008

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C E R T I F I C A T E

This is to certify that the thesis entitled *"Estimation of biogas potential of the food waste generated in a hostel mess"* submitted by **Mr. Pravin Kumar** [Roll No. 111BT0570] in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Biotechnology at National Institute of Technology, Rourkela is an authentic work carried out by him under my guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

Prof. P. Balasubramanian

Assistant professor

Department of Biotechnology and Medical Engineering
National Institute of Technology
Rourkela-769008

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PRAVIN KUMAR

ABSTRACT

This research work focusses on the estimation of biogas production from the food waste collected from a hostel mess in National Institute of Technology Rourkela. Vikram Sarabhai Hall of residence being the biggest hostel in the institute generates enough food waste and has a huge biogas potential. This paper focusses on the theoretical estimation of biogas that is an initial step towards establishing a biogas plant at the backyard of the hostel. Along with the waste treatment technology available today, characterization and chemical analysis of the raw material supplied to the machine becomes exceptionally important when figuring out the design and operational parameters of the biogas plant. Thorough research both quantitative and qualitative parameters are very important prior to the establishment of any engineering model. A food waste sample was collected from the hostel mess. In order to do the qualitative analysis and characterisation of food waste, the sample was dried in hot air oven and further it was crushed using the mortar pistol to powdered form. This powdered sample was subsequently used for characterisation of the food waste. Characterisation process includes the carbohydrate estimation, protein estimation, cholesterol estimation and CHNS analysis. This research work includes an MATLAB tool that was used to theoretical estimate the methane generation if the CHNS data is known to us. Even though very few number of samples were analysed, the results are extremely valuable for the biogas plant designers.

KEY WORDS: biogas, food waste, biogas plant, proximate analysis, ultimate analysis.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUTION

There are two very important reasons for the world to think about an alternative source of energy. The first reason is from the geological perspective, the global production of biogas might peak in the coming few decades. The second being the very obvious, that is the carbon dioxide production and its consequences. There are many countries across the globe have started establishing an industrial scale and full-fledged biogas generation, while in India this concept is still in its developmental stage.

Improved energy security and environmental change alleviation are the principle drivers for the change of the energy framework from fossil to renewable sources. Biomass needs to assume a key part in this change to a low carbon economy. Around the world, biomass (counting putrescible waste and food waste) represents more than 66% of all renewable energy supplies. (Andritz, accessed April 2015) Among biomass sources, biogas is a fascinating alternative with a vast potential, offering numerous energizing conceivable outcomes to supplant and subsequently lessen our reliance on fossil fuels. (Oleskowicz-Popiel, 2008)

The first biogas plant was built in a colony in Bombay. (Pillay, 2011) Since then it has become quite popular across the globe. Anaerobic digestion is a progression in which microorganisms dissect decomposable solid in the lack of oxygen. The procedure is extensively used to treat waste water slurry and manufacturing and ranch wastes as it provides volume and mass reduction of the input material. Anaerobic digestion is pondered a basis for renewable energy because the methane-rich biogas formed is suit-able for energy generation and is a substitute for fossil fuels. Moreover, the nutrient-rich mass and slurry left after assimilation can be used as manure.

According to a survey of food waste conducted in the year 2011 by the United Nations every year about 30 % of the consumable food produced by humans goes to waste which is a big amount summing around 1300 tonnes of food waste. (Jenny Gustavsson, 2011) If this amount of food waste is used it would generate around 350 kilolitres of biogas for every tonne of bio mass, out of which two third would be methane gas (Gray, 2008) and with an estimated energy of 6.25 Wh/litre of biogas (Methodology for determining refernece costs of electricity generated from renewable resources, 2009). Anaerobic digestion has an additional advantage; disposable waste would not be sent to landfills for dumping that would further reduce a lot of logistics and transportation cost.

According to Central Pollution Control Board (CPCB) and the National Environmental Engineering Research Institute (NEERI) survey conducted across the country following statistics were observed (7)
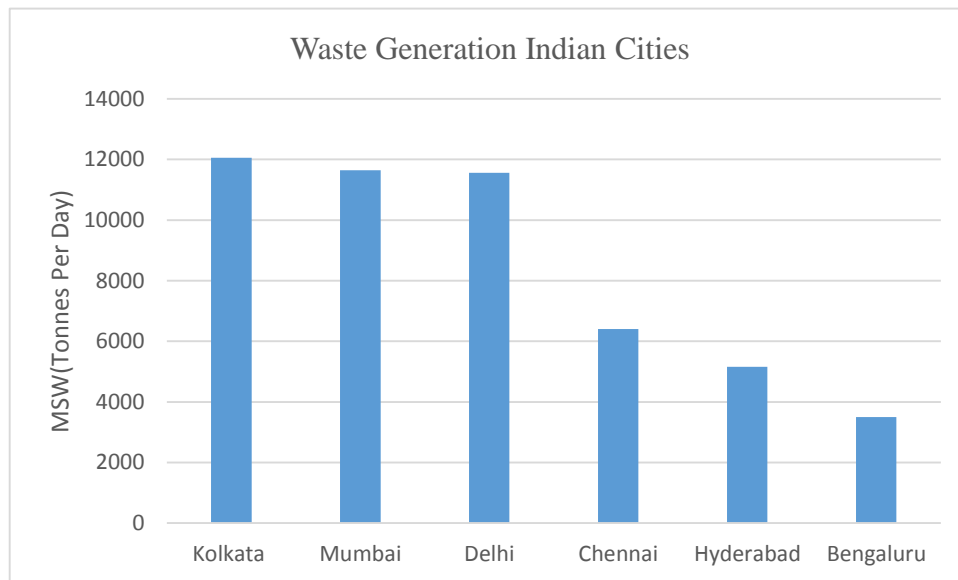
Figure 1 Distribution of waste generation in Indian cities

As can be seen from figure 1 biogas industry has huge potential in India and could be a crucial factor in bringing down the energy deficit of the country. Below is the table showing MSW (municipal solid waste) generated in different cities (Sustainable Solid waste management India, 2011).
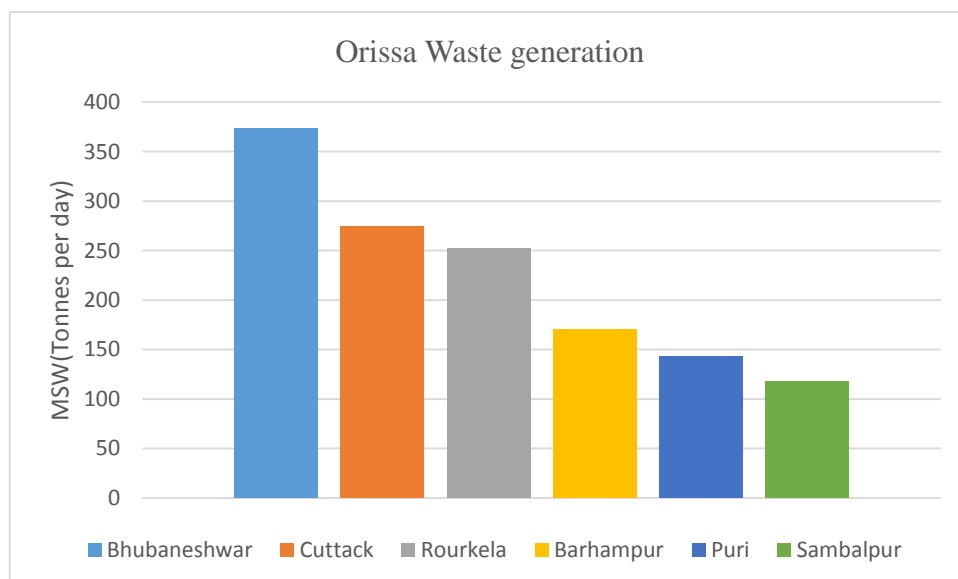
Figure 2 Distribution of Waste generated in Odisha cities

Now coming to the very basic level that is our institute and further narrowing the research and analysing the data of the food waste generated in a hostel mess, as it can be seen in figure 3 that a lot of wastes is being discarded every day.

Figure 3 Distribution of food waste generated in Hostel mess

Kitchen waste is a rich source of methane produced as a result of anaerobic assimilation. This report begins with the need of biogas as a renewable source of energy, moving further there are few experiments for characterisation of food waste and furthermore a programme to approximate methane production and at last conclusion.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

This section is an evaluative report of information found in various articles, journal paper, books and report related to the area study. This includes a theoretical base for the area of study. Some of the topics include food waste chemical composition, biogas generation process and principles of anaerobic digestion

2.1 BIOGAS CHEMICAL COMPOSITION AND PROPERTIES

Biogas is a combination of gases which are produced as a result of decomposition of organic matter such as food waste in the absence of oxygen. It can be produced from feedstock such as municipal waste, waste from agricultural activities or kitchen waste. Over the past few years the biogas production has become more efficient. The primary goal while establishing an anaerobic digestion facility is to stabilise the whole bio mass (M. Herout, 2011). The basic composition of biogas largely is affected by a variety of factors such as material used for degradation and other chemical variations can result in a different composition. The following table shows the generalised data of concentration of different gases present in a biogas container (Fulekar, 2010).

Table 1 Biogas composition

Bulk Biogas Components	Trace Components
Methane	50-70%
Carbon Dioxide	30%-40%
Hydrogen	5%-10%
Nitrogen	1%-2%
Water Vapour	0.3%
Hydrogen Sulphide	Small traces

If one-metre cube of biogas is available with no carbon dioxide in it, the energy content comes out to be 10kWh.(10)So it can be deduced that the energy content of the gas is in direct

proportion to the amount of methane in the container. So if one-metre cube of biogas is taken based upon above table if the methane percent is considered to be 60 % we can expect energy output to be 60kWh.

2.2 CHEMICAL PROPERTIES OF BIOGAS

Chemical properties of a mixture can be studied by studying chemical properties of its constituents. Biogas mainly contains methane, carbon dioxide, water vapour and traces of hydrogen sulphide and ammonia. This section discusses chemical properties of various constituents of biogas.

Methane

Methane molecule is made of one carbon atom and four hydrogen atoms covalently bonded to the central atom forming a tetrahedral molecule. This gas is produced by methanogenic bacteria by decomposing organic matter in the absence of oxygen that is commonly known as anaerobic digestion. It has a density of 0.72 kg/m^3 which makes it lighter than air. (Fulekar, 2010) It has a high calorific value of 9-11KWh/Nm^3 (Fulekar, 2010) which forming almost two third portion of biogas makes it an excellent source of energy. Methane is non-poisonous yet at the same time it can form flammable mixtures with air. Due to its high calorific value it can be explosive if it is present in the concentration of 5-15% in the air. (Pellerin, 1987) The higher the percentage of methane in biogas higher is the energy content of the biogas.

Carbon Dioxide

One of the most abundant gases in the atmosphere carbon dioxide is made of one carbon atom and two oxygen atoms. This is a very important gas for the plant life as this is needed during the process of photosynthesis. This is a colourless and odourless gas at low concentrations but smells acidic at high concentrations. CO_2 is produced by combustion or burning of organic matter or by microbial fermentation. This is almost one-third of the total biogas mixture. This comes out as a by-product with CH_4 when the methanogen bacteria decompose the organic matter such as carbohydrate and fatty acids. Biogas mixture with high CO_2 can hamper the overall energy efficient biogas mixture (Bothi, 2007). Also high CO_2 in the biogas mixture can affect the pH of the biogas and can make it acidic. Removal of CO_2 from biogas is not economically feasible.

Other Components

Apart from the major components carbon dioxide and methane other traces include ammonia, water vapour and hydrogen sulphide (H_2S). Other traces account for less than 5 % of the total biogas concentration. According to the requirement traces should be removed from the biogas container. Water vapour along with hydrogen sulphide can form corrosive acidic environment inside the container. Hydrogen sulphide is toxic and corrosive as it can damage the pipelines and other instrumentation which directly affects the durability of the biogas plant and hence making less economical. Even during the combustion process of the biogas hydrogen sulphide produces sulphur dioxide that is an air pollutant and therefore contributing to the pollution. During the anaerobic decomposition if the mixture contains more than 6% H_2S, it will adversely affect the methanogens process and henceforth brings down the methane yield (Chynoweth, 1987) "Iron Sponge" (iron soaked in wooden chips) can be used to bring down the hydrogen sulphide concentration in the biogas mixture.

2.3 STEP WISE PROCESS FOR PRODUCTION OF BIOGAS

Below is a step by step guide on how to produce biogas from the food waste

- Collecting Waste: Food waste is collected from the backyard of the hostel. The unnecessary items for anaerobic digestion such as polythene bags and plastic can be separated out because they can interfere the proper functioning of the digester
- Prior- Treatment: This is a very important step, in this we add chemicals from outside that can enhance the digestion process.
- Making the mixture uniform**:** Mixture should be uniform so as to increase the efficiency of the whole process. If the mixture is not uniform than there may be parts in the container where microbes have plenty of food waste to digest whereas in the same place there might be one place where microbes are dying due to scarcity of foo waste. Also it is easy for microbes to feed on smaller pieces.
- Substrate feeding**:** Biogas can be produced by feeding a variety of substrates such as kitchen waste, municipal waste. Feedstock should be an organic matter only. The substrate should not include wood, because the bacteria can't decompose this easily.
- Feedstock digestion**:** Digestion or decomposition of the organic matter used in the above step takes place in the absence of oxygen. This process is commonly known as anaerobic digestion

- Biogas Production**:** After the anaerobic digestion is complete biogas is produced which is stored in the container and can be utilised as a fuel. Outlet valve regulates the flow of biogas.
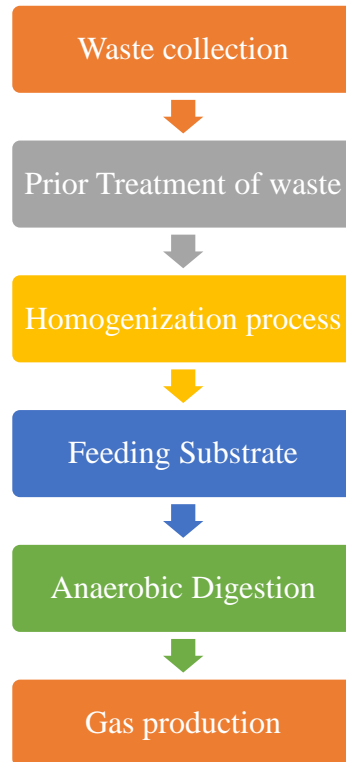

Figure 4 Flow chart representing step wise process for biogas production

2.4 ANAEROBIC DIGESTION PRINCIPLE

Anaerobic processing is a methodology which happens without oxygen. Amid this procedure different microorganisms are included which breakdown the natural substances through different biochemical methods that at last result in biogas and processed slop that is rich in supplements. In this process the bacteria involved depend on each other and hence it can be said that this is a symbiotic process.

Various stages for anaerobic digestion are mentioned below:

- Hydrolysis: The very step in the anaerobic digestion process which involves breakdown of complex molecules into simpler ones. Carbohydrates are broken down into monosaccharides, proteins are broken down into amino acids and likewise fat is broken down into fatty acids. This initial step is the slower process as compared to other steps and hence it limits rate of digestion process. Wood should be separated from the

biomass added to the container in the initial phase as it contains lignin and which is not easily hydrolysed. (Ostrem, 2004) This process can be represented by a simple equation shown below.
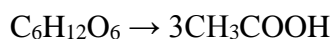
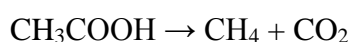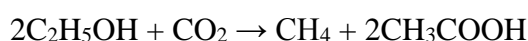$$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$$
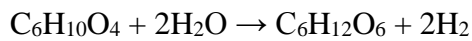
It can be seen from the above reaction that the complex molecule breaks down into simple sugar such as glucose.

- Acidogenesis: Second step in the anaerobic digestion process, in this step the bacteria utilize the products of the first stage to produce acid. Most common acid produced during this stage include butyric acid, propionic acid and acetic acid. Carbon dioxide and hydrogen gas are also produced during this stage. Bacteria present in this stage create suitable conditions for anaerobic bacteria by consuming all the oxygen present in the container. Below equations demonstrate how glucose is converted into acetic acid.

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

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

$$C_6H_{12}O_6 \rightarrow 3CH_3COOH$$

The above equation shows how glucose is converted into ethanol in the first equation, then into propionate and third equation shows the formation of acetic acid.

- Methanogenesis: This is the final stage of the anaerobic digestion process. In this stage bacteria utilise the acids formed in the previous step to produce methane and carbon dioxide gas. The bacteria in this step are strictly anaerobic and are called methanogens. The major composition of biogas is produced during this stage. Following equations show the formation of methane (Verma, 2002)

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

Hydrolytic and fermentative bacteria decompose organic materials

Cellulose degrading bacteria digest polysaccharide to monosaccharide

Protein degrading bacteria digest protein to amino acids

Fat degrading bacteria degrade fat to fatty acids

Volatile acids like acetic acid, H_2 and CO_2
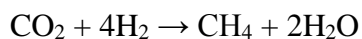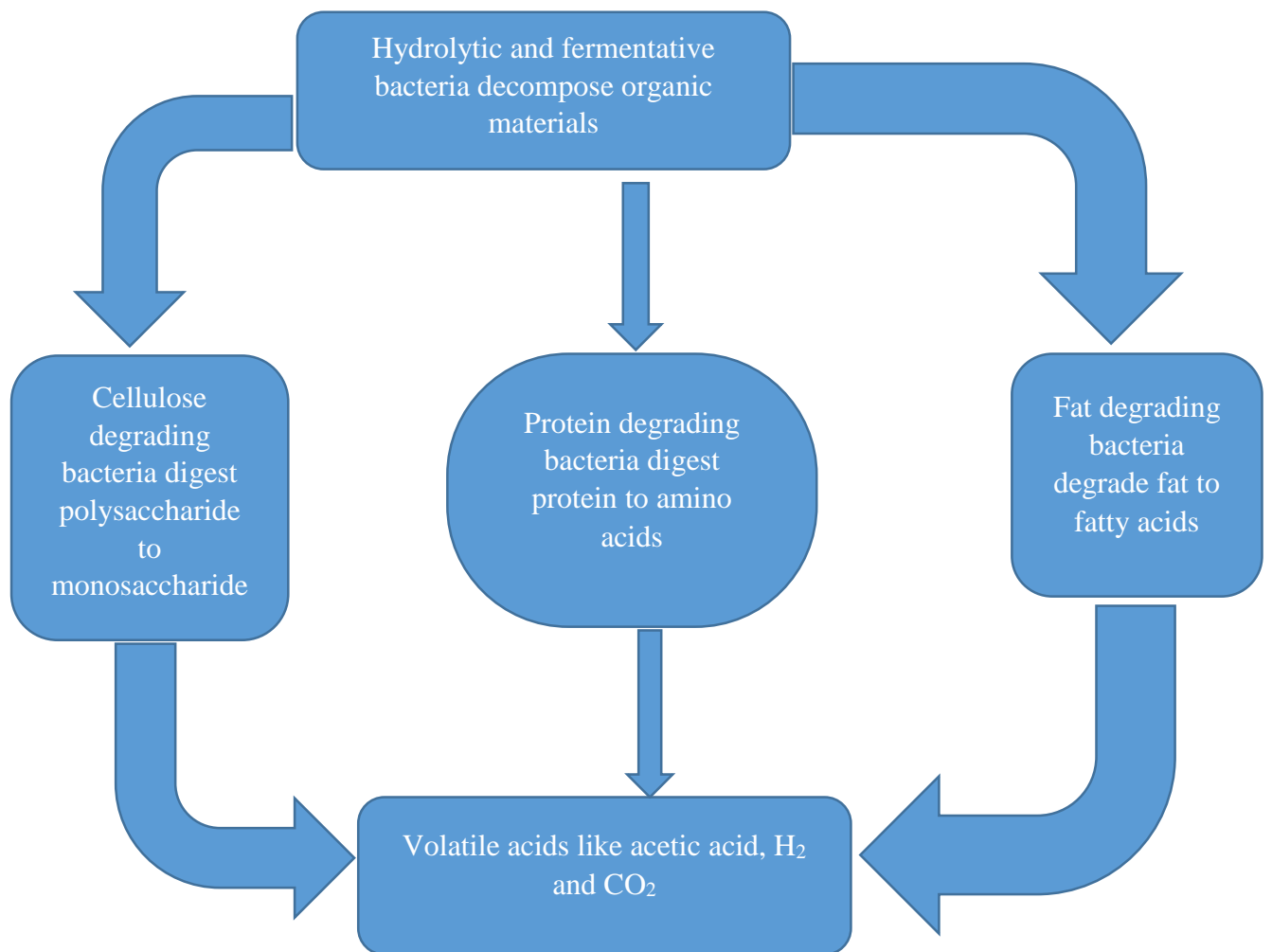
2nd stage: Acidification

Acidogenic bacteria convert the molecules produced in first stage

Acetic acid, Hydrogen and carbon dioxide
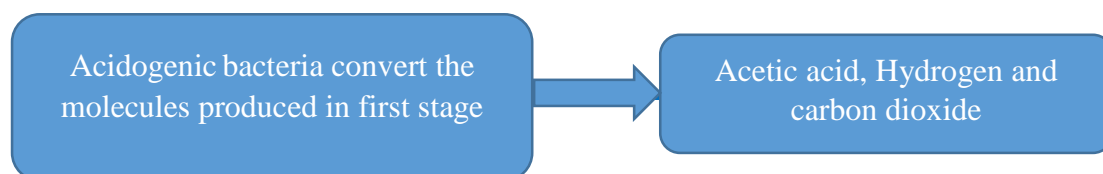
3rd stage: Methanogenesis

Methanogenic bacteria decomposes the molecules present in 1st stage and 2nd stage

Methane and carbon dioxide

Figure 5 Diagram representing anaerobic digestion process

CHAPTER 3

MATERIALS AND METHODOLOGY

3.0 MATERIALS AND METHODOLOGY

This section describes methodology to be followed for estimating biogas potential of the food waste. Wet food waste sample was collected from Vikram Sarabhai Hall mess, it was then dried in a hot air oven, the dried sample was then crushed into powdered form and this sample was analyzed for moisture content, carbohydrate content, protein content and CHNS percentage composition.
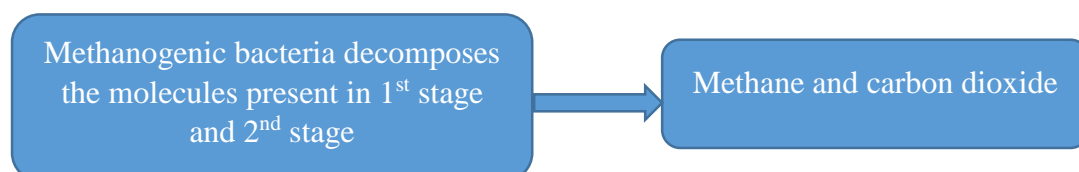
3.1 MOISTURE CONTENT

This experimented is conducted to measure the amount of solid matter present in the sample. When collecting the sample it can be observed that it is in the semi-solid state, so in order to measure the amount of solid organic matter this experiment was conducted. This experiment gives us an estimation of solid matter present in the food waste sample collected from the mess. Also this experiment is very useful as the sample obtained after crushing the dried food waste sample was utilised to conduct subsequent experiments. Following experiment was conducted as per standard methods with slight alterations (Clesceri, 1998)

Moisture content (%)

Moisture indicates the amount of liquid most specifically water, which can be present in trace amounts. Most of the organic matter contains moisture, depending on the matter into consideration it varies from low moisture content to high amounts. There is a totally different science known as aquametry, study of water content in a sample. Moisture effects different materials differently, if moisture is not removed from food samples for a long time, fungus and bacteria starts to grow and finally decompose the sample.

Since the boiling point of water is 100 degree Celsius so if the sample is heated above 100 degrees for quite a long time water present in the sample evaporates and leaves behind the solid organic matter.

Equipment and material required

- Petri Plate
- Hot air oven
- Digital weighing machine
- Food waste from hostel mess

Protocol:

- Food waste sample was collected from the backyard of the hostel mess.
- Initial weight of the dry, empty petri plate was measured.
- Food waste sample was weighed along with the petri plate on the weighing machine.
- This petri plate with the food waste sample was kept in the hot air oven at a temperature of 105 degree Celsius for 10 hours
- Petri plate containing the dried food waste sample was allowed to cool down in a desiccator.
- Petri plate with food waste sample was measured on the weighing machine.
- The sample was again put inside the hot air oven for an hour at the same temperature mentioned above.
- These steps of drying the sample, cooling it in the desiccator and measuring weight were repeated till constant weight was observed (Y gm).
- After observing constant weight moisture content of the sample was measured using the following calculations.

Calculations:

Moisture content of the sample = (Weight of the dried sample / Initial weight) * 100

$$= (Y/X) * 100$$

Where, X = weight of petri plate + wet food waste sample

Y = weight of petri plate + dried food waste sample

3.2 CARBOHYDRATE ESTIMATION

Carbohydrate is an organic molecule which consists of Carbon(C), Hydrogen (H), and Oxygen (O) atoms. Carbohydrates are the main composition of food consumed by humans, so also a main constituent of food waste generated in the mess. Quantitative estimation of carbohydrate is necessary so that it can be observed which enzyme to use in order to enhance the production of methane from the food waste.

Following experiment was conducted for the quantitative estimation of carbohydrates using anthrone in the food waste sample. (Hedge, 1962) Glucose reacts with hydroxymethyl furfural that further reacts with anthrone to give blue, green complex. This green complex shows absorption maximum at 630 nm.
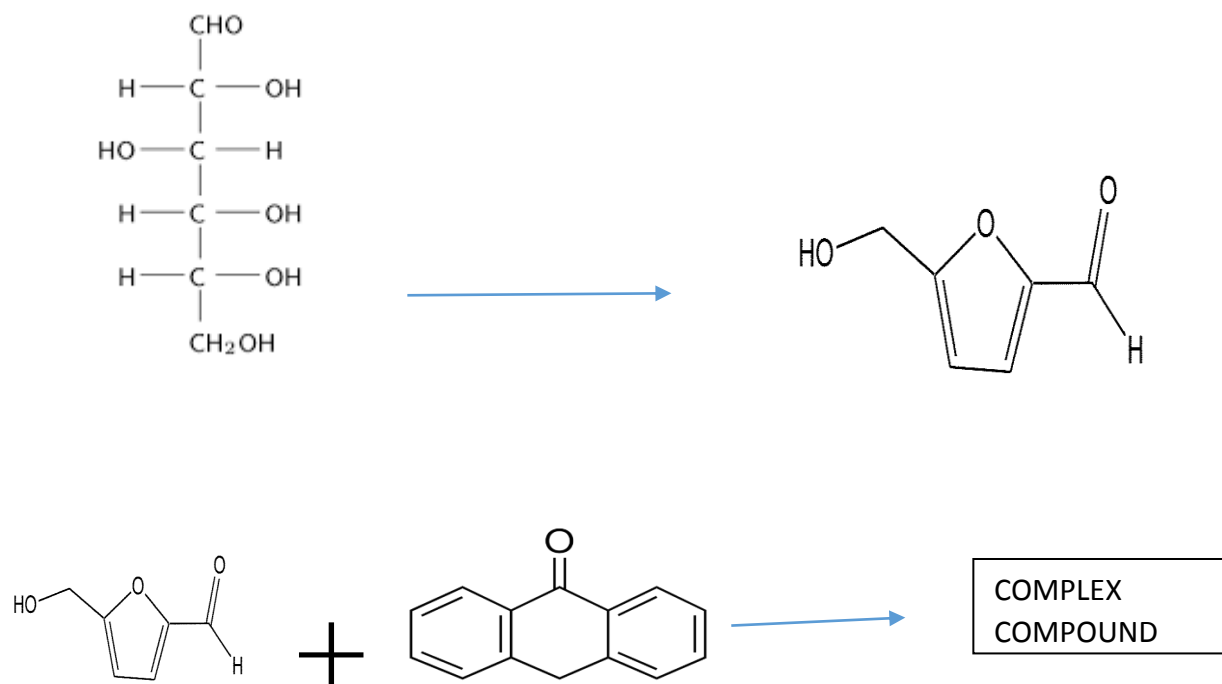
This experiment was conducted as per standards with slight modifications (Hedge, 1962)

Materials:

- Anthrone Reagent: weigh 200 mg of anthrone and dissolve it in 95 % sulphuric acid solution
- Glucose solution
- Weighing machine
- Conical flask

Protocol:

- 200 mg of anthrone was dissolved in 100 ml of 95 % concentrated sulphuric acid.
- This anthrone reagent was kept in a refrigerator at a temperature of -10 degree Celsius for an hour.

- 100 mg of was glucose was dissolved in 100 ml of water.
- 1 ml of stock was diluted to 10 ml with distilled water.
- The sample for the standard curve was prepared to take 0, 0.2, 0.4. 0.6, 0.8 and 1 ml of the working standard. A blank solution with 0 ml glucose solution was prepared as mentioned in Table 1.
- Volume was made up to 1 ml by adding distilled water and 1 ml of the test sample were taken in different test tubes.
- 4 ml of anthrone reagent was added to each sample.
- All of the above samples were kept in a boiling water bath for 10 minutes.
- Absorbance of all the samples mentioned above was measured at 630 nm in a spectrophotometer
- A standard curve was plotted with absorbance on "Y" axis and concentration on "X" axis.
- The concentration of the unknown sample can be measured by measuring the optical density in a spectrophotometer at a wavelength of 630 nm.

Table 2 Tabular data for standard curve (carbohydrate estimation)

Tube No.	Blank	1	2	3	4	5
Conc. of Glucose (mg/ml)	0	0.2	0.4	0.6	0.8	1
Glucose stock soln. (ml)	0	0.2	0.4	0.6	0.8	1
Water (ml)	1	0.8	0.6	0.4	0.2	0
Anthrone reagent (4ml)	4	4	4	4	4	4

Concentration of the glucose in undiluted sample (mg/ml) =

Concentration of glucose in diluted sample (mg/ml)

*dilution factor

3.3 PROTEIN ESTIMATION

Proteins are natural polymers composed of amino acid units joined one to another by peptide (or amide) bonds. Proteins are hydrolysed by extracellular enzymes (called proteases) into their constituent polypeptides and amino acids. In anaerobic reactors, however, proteolytic bacteria predominantly mediate protein degradation and the processes involved are energy yielding. Most studies have shown the main proteolytic bacteria in digester sludge are gram-positive bacteria, principally from the genus Clostridia and these play a dominant role in the fermentation of amino acids as well (MJ, 1988)

Following experiment was conducted for quantitative estimation of protein in the food waste sample. The Bradford assay is a protein determination method that involves the binding of Coomassie Brilliant Blue G-250 dye to proteins (Bradford, 1976). This dye combines with the protein to form a complex that shows absorption maximum at 595 nm.
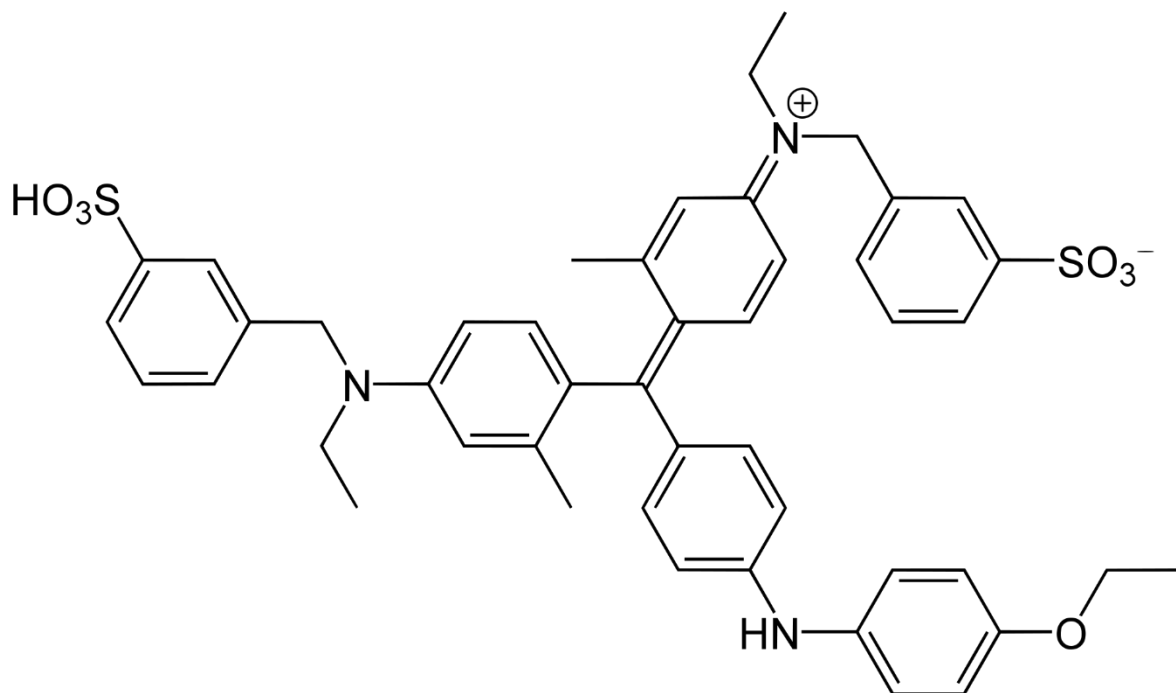

Figure 6 Coomassie Brilliant Blue G-250

Materials:

- Bovine serum albumin(BSA)
- Bradford reagent
- Weighing machine
- Conical Flask

Protocol:

- A stock solution of concentration 1 mg /ml was prepared.
- Five samples of concentration 200, 400, 600, 800 and 1000 µg/ml were prepared for the standard curve.
- These samples were made up to 1 ml with distilled water.
- Blank was prepared keeping the concentration "0".
- 1 ml water Bradford reagent and 2 ml water were added to the samples
- All the above samples were kept in dark for 20 minutes.
- Absorption maximum at a wavelength of 595 nm was observed using spectrophotometer
- A standard curve was plotted with concentration (µg/ml) on "X" axis and absorption on "Y" axis.
- The concentration of protein in the unknown sample was measured using the OD value observed from the spectrophotometer.

Table 3 Tabular data for standard curve (protein estimation)

Tube No.	Blank	1	2	3	4	5
Conc. of BSA (µg/ml)	0	200	400	600	800	1000
BSA stock soln. (ml)	0	0.2	0.4	0.6	0.8	1
Water (ml)	1	0.8	0.6	0.4	0.2	0
Bradford reagent (ml)	1	1	1	1	1	1

3.4 CHNS ANALYSIS

Percentage of different elements (Carbon, Hydrogen, Nitrogen, and Sulphur) in the sample helps to find out the following information:

- This data is very important for theoretical estimating the biogas potential of the organic waste using the equation in the section 3.2
- For the ammonia intoxication C: N ratio is very important.
- Sulphur can inhibit the methanogens and hence to figure out the amount of sulphur to be taken out that is desulphurization, so that the biogas plant works properly and it does not affect its overall efficiency.

CHNS analyser helps to find out this data for organic compounds, it works on the principle of "Dumas Method". This method involves instantaneous combustion of the sample which is commonly known as "flash combustion". Column chromatography is used to separate different combustion products. Depending on the concentration of the products this instrument generates a signal proportional to the concentration.

Working Principle:

Apart from this technique there are a lot of other methods available to measure the CHNS, but this method brings out a totally different approach with most accurate and precise values within a very short span of time. Combustion products CO_2, SO_2, NO_2 and H_2O are released out of chromatographic column and are detected by Thermal Conductivity Detector.

The instrument is very reliable as the gases released after combustion are not at all diluted as they are directly taken into the Gas Chromatographer. Thermal Conductivity Detector, combustion reactors, auto sampler and combustion reactors are major parts of the CHNS analyser.
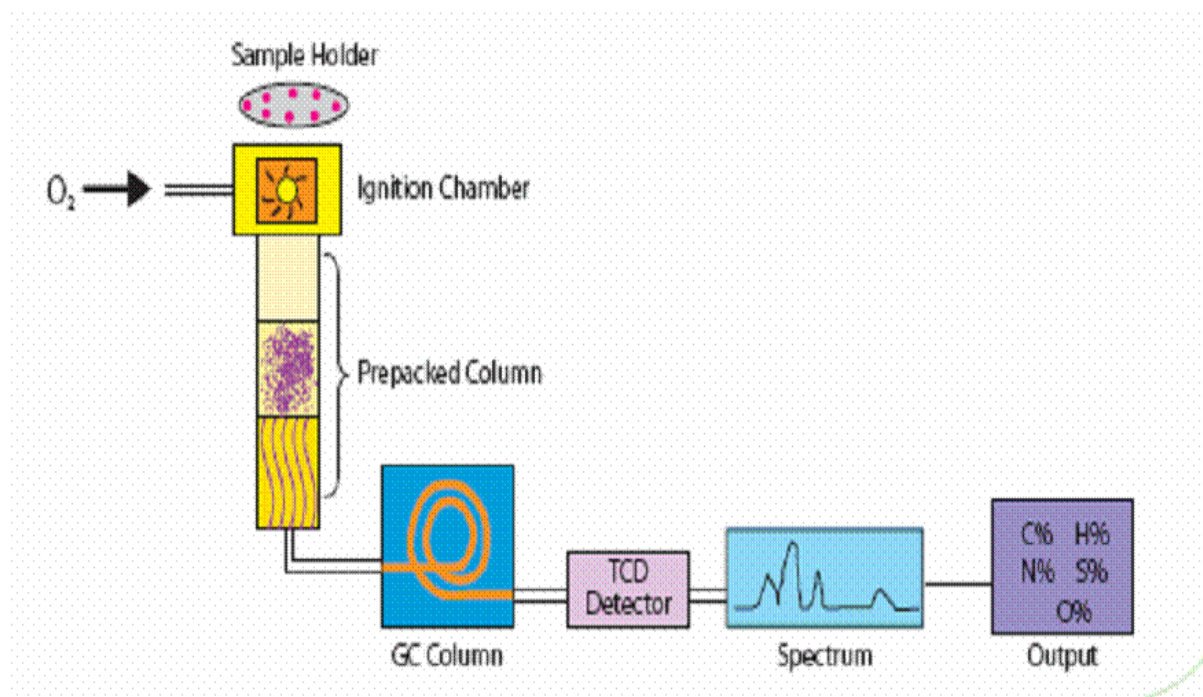
Figure 7 Digramatic representation of CHNS analyzer (Sophisticated Analytical Instrument Facility, n.d.)

Materials Required:

- Food waste sample
- Digital weighing machine
- Small aluminium cups for holding the sample
- CHNS analyser

Protocol:

- Dried food waste sample was measured using a weighing machine. The weight of the sample was to be taken in the range of 5-10 mg.
- The sample in the above step was collected in a small aluminium cup.
- This sample along with the aluminium cup was flattened and this sample was used to get the CHNS data.
- CHNS data was observed after 24 hours

3.5 MATHEMATICAL MODELLING

A system that uses mathematical equations and concepts is called mathematical model. This process of developing that system is called mathematical modelling.
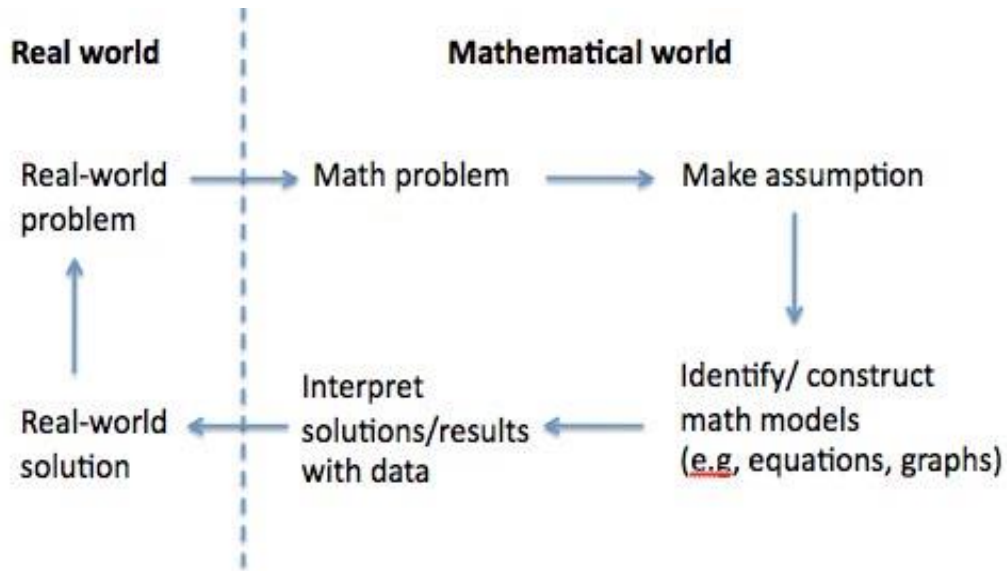
Figure 8: Schematic representation of mathematical modelling

From the data obtained from CHNS analyser, theoretical biogas yield can be calculated using the following equation by Muller and Buswell (Buswell, 1952).

$$C_c H_h O_o N_n S_s + \left(c - \frac{h}{4} - \frac{o}{2} + \frac{3n}{4} + \frac{s}{2}\right)H_2O \rightarrow \left(\frac{c}{2} + \frac{h}{8} - \frac{o}{4} - \frac{3n}{8} - \frac{s}{4}\right)CH_4 + \left(\frac{c}{2} - \frac{h}{8} + \frac{o}{4} + \frac{3n}{8} + \frac{s}{4}\right)CO_2 + nNH_3 + sH_2S$$
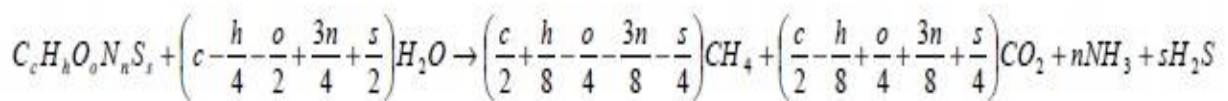
Algorithm:

STEP 1: Enter moles of carbon, hydrogen, nitrogen, oxygen and sulphur.

STEP 2: Calculate number of moles of H_2O, CH_4, CO_2, NH_3, and H_2S

STEP 3: Display number of moles of H_2O, CH_4, CO_2, NH_3, and H_2S

STEP 4: Calculate and display the percentage of NH_3, CH_4, CO_2, and H_2S.

STEP 5: Calculate and display the percentage of CH_4 and CO_2 when nitrogen and sulphur are excluded.

Calculations:

The program in MATLAB was executed and further entering the values for the empirical formula for the kitchen waste (Banks, 2009). After entering the empirical formula values and using Buswell equation 55% CH_4 and 45% CO_2 was calculated.

Average food waste generated in a day in the mess is 634 kg.

CHAPTER 4

RESULTS AND DISCUSSION

4.0   RESULTS AND DISCUSSION

This section includes all the experimental data that was obtained after performing a series of experiments described in section 3. Data obtained was further analysed using bar graph and other statistical tools. As per a report food waste generated in Vikram Sarabhai Hall during March 2014 was found to be (Kumar, 2014)

Table 4Waste generation in Vikram Sarabhai Hall during March 2014

Day	Uncooked Food Waste (L)	Cooked Food Waste (L)
1	150	350
2	150	300
3	150	300
4	200	350
5	150	300
6	150	350
7	200	400

And it can be seen from figure 3, average food waste produced during the month of February 2015 is coming out to be 634 kg. The average food waste generation in the mess has gone up in the last year.

4.1   MOISTURE CONTENT

Results of the experiment described in section 3.1 are represented in tabular form in table 4. I. Weight of the wet sample was measured using weighing machine and weight of the dry sample was again measured and this data was used to calculate moisture content in the sample.

Table 5 Moisture content data

SAMPLE	INITIAL READING (in gm)	FINAL READING (in gm)
1	48.333	13.718
2	35.327	10.792
3	45.583	12.507
4	41.659	12.126
5	35.624	10.733

Most of the water gets evaporated when the cycle of heating and weight measuring was repeated. So once constant reading is observed that means there is no more water left in the sample. Henceforth the moisture percentage in the sample can be measured.
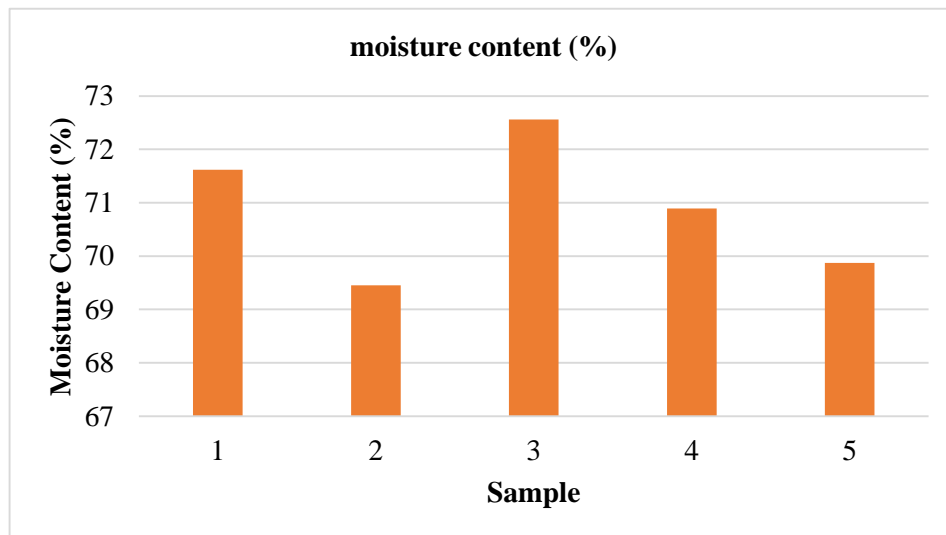

Figure 8: Distribution of moisture content in food waste samples

Moisture Content (%)

From table 4 and figure 8 it can be deduced that most part of the food sample is water. Average moisture content is coming out to be 70.88 % , so after evaporating all the moisture it can be seen 29.12 % of the original sample is solid.

4.2   CARBOHYDRATE ESTIMATION

Results of the experiment described in section 3.2 are represented in table 5. Table 5 represents absorbance data obtained from spectrophotometer. Table 5 includes data for plotting standard which was used to measure the carbohydrate percentage for the samples discussed in table 6.

Table 6 Absorbance value for standard curve for carbohydrate estimation

concentration (mg/ml)	absorbance at 630 nm
0.2	0.48
0.4	0.69
0.6	0.79
0.8	0.91
1	1.12

It can be observed from table 6 that increasing the concentration of carbohydrates in the sample absorbance also increases. It can deduced that concentration of the sample is directly proportional to the absorbance of the sample.
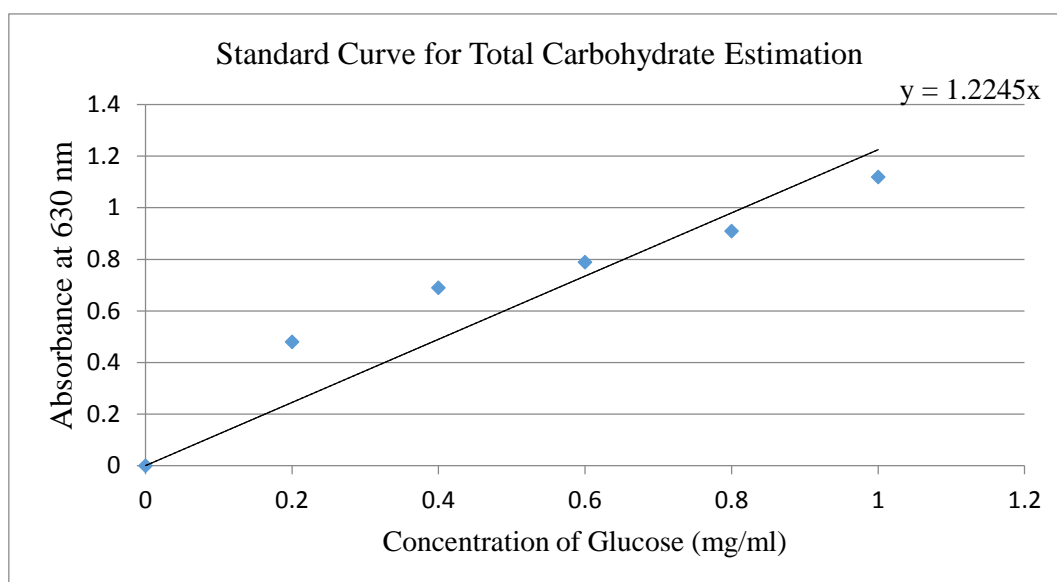

Figure 9 Standard curve for carbohydrate estimation

Figure 9 shows the standard curve which was used to find out the carbohydrate content in the food waste sample. After getting the linear equation can be used to calculate the amount of carbohydrate in the unknown sample by simply using absorbance data and slope of the linear curve in figure 9.

Table 7 Carbohydrate concentration for unknown samples

Sample	Absorbance at 630nm
1	0.65
2	0.691
3	0.711
4	0.519
5	0.612

Using the absorbance data in Table 6 and using the linear equation displayed in figure 9 the moisture content of all the five unknown concentration food waste samples was calculated. Carbohydrate content in the five samples is represented in the form of bar graph on the next page in figure 10.
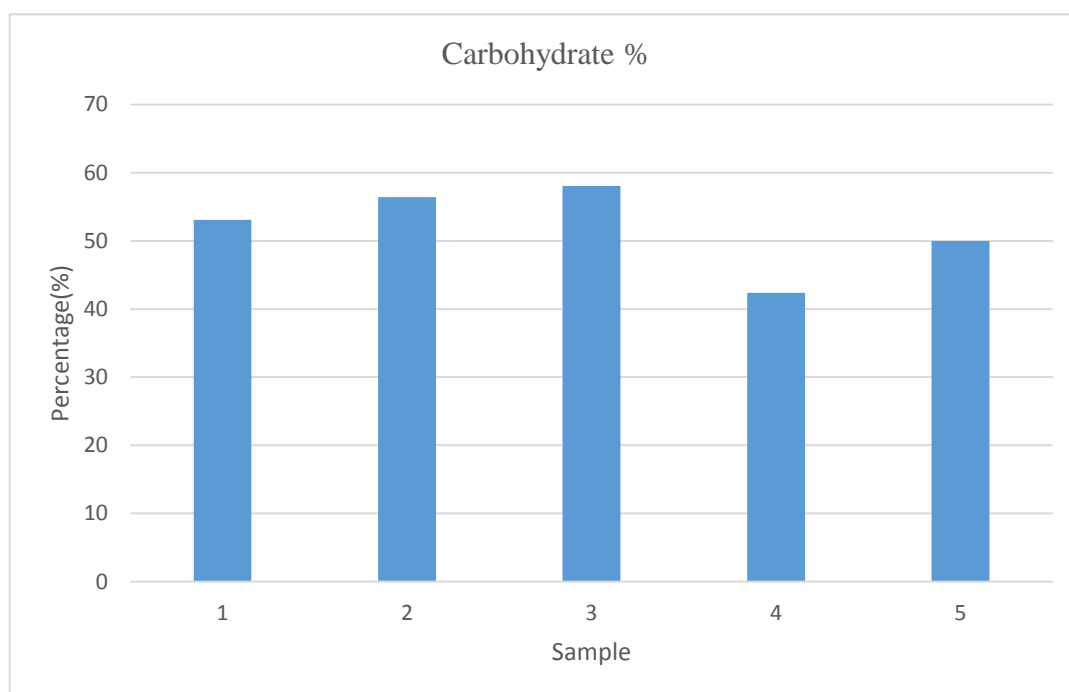

Figure 10 Bar graph representing carbohydrate percentage in food samples

Average carbohydrate concentration in the five unknown samples is coming out to be 51.99%. It can be seen major portion of our dried food waste sample is carbohydrates. This carbohydrate is decomposed during the process of anaerobic digestion described in section 2.4 to give simple molecules.

4.3   PROTEIN ESTIMATION

Results of the experiment described in section 3.3 for preparing the standard curve for protein estimation is represented in the table 7. Spectrophotometer can detect very low concentration of protein. Proteins are complex molecules which are broken down into simpler molecules by the bacteria present in the food waste sample.

Table 8 Absorbance data for protein estimation (standard curve)

concentration (µg/ml)	absorbance (at 595 nm)
200	0.225
400	0.451
600	0.697
800	0.931
1000	1.107

It can be seen from the data in Table 7, absorbance value is increasing as the concentration of the sample was increased. We can deduce that concentration and absorbance are directly proportional.
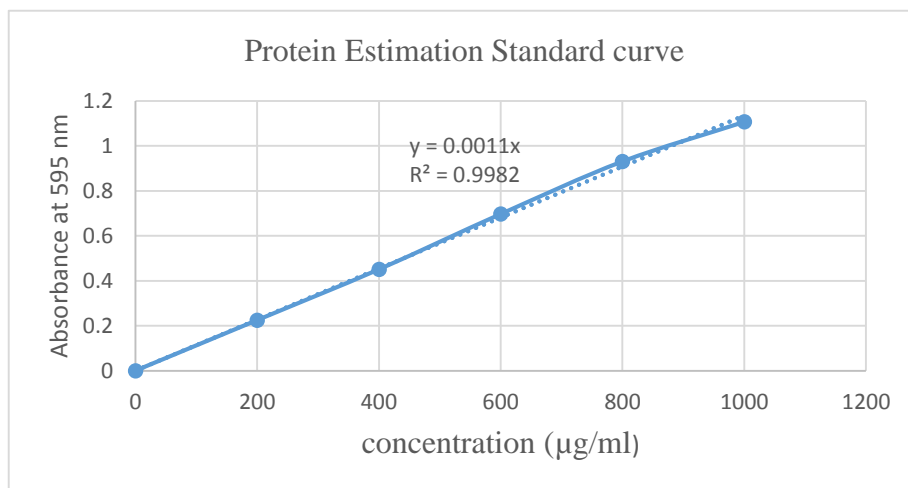

Figure 11 Standard curve for protein estimation

Figure 11 represents standard graph for protein estimation. Linear equation y=0.0011x can be used to find out the protein concentration of the samples with unknown concentration. Data can be simply used for the coordinates and the concentration of protein in the sample can be calculated.

*Table 9 **Protein concentration for unknown samples***

sample	absorbance
1	0.169
2	0.153
3	0.148
4	0.173
5	0.152

Table 8 represents unknown samples with their absorbance data. Concentration of the sample can be calculated using the linear equation in the figure 11. It can be seen from the bar graph figure 11, distribution of protein percentage in the samples with unknown concentration.
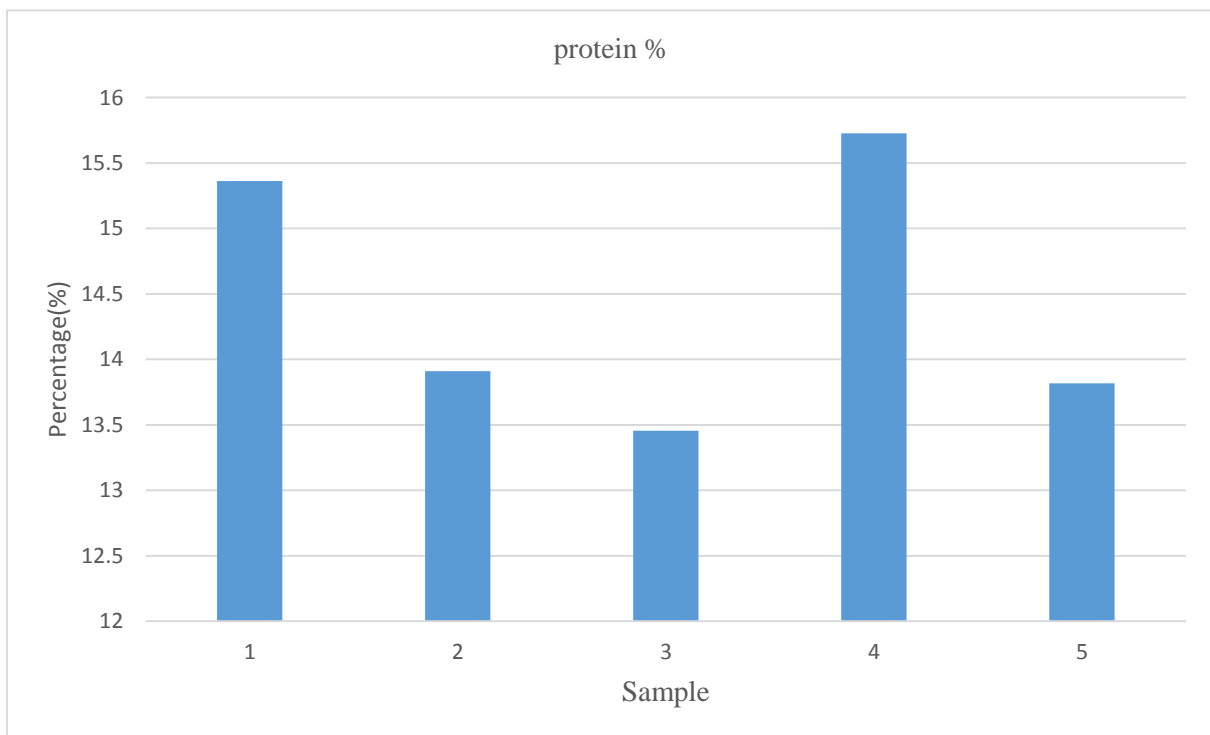

Figure 12 Distribution of protein percentage in food samples with unknown protein concentration

Protein percentage in the food samples after using the data in table 8 is represented in bar graph in figure 12.Proteins are broken down into simpler molecules by the bacteria present in the biogas plant. From the data in table 12 average protein percentage can be calculated in the samples. Average protein percentage in the sample was found to be 14.45 %.

4.4   CHNS ANALYSIS

CHNS analysis is very important for calculating C:N ratio of the food samples. Dry food waste sample is used to calculate this data. Table CHNS percentage was calculated using the facility available at the NMR spectroscopy laboratory in National Institute of Technology Rourkela, Odisha (India). It can be seen from the data in table 9 C:N ratio is 10:1.

Table 10 CHNS(O) percentage in different food samples

weight in mg	N %	C %	H %	S %	O%
8.18	4.393	41.981	5.596	0.210	45.817
8.86	4.074	42.157	5.907	0.173	45.687
8.52	4.234	42.069	5.751	0.192	45.752

C:N ratio should be high because if the nitrogen concentration is high that can corrode the biogas plant. If the Nitrogen percentage in the sample is high that can reduce the overall yield of the biogas generated from food waste.
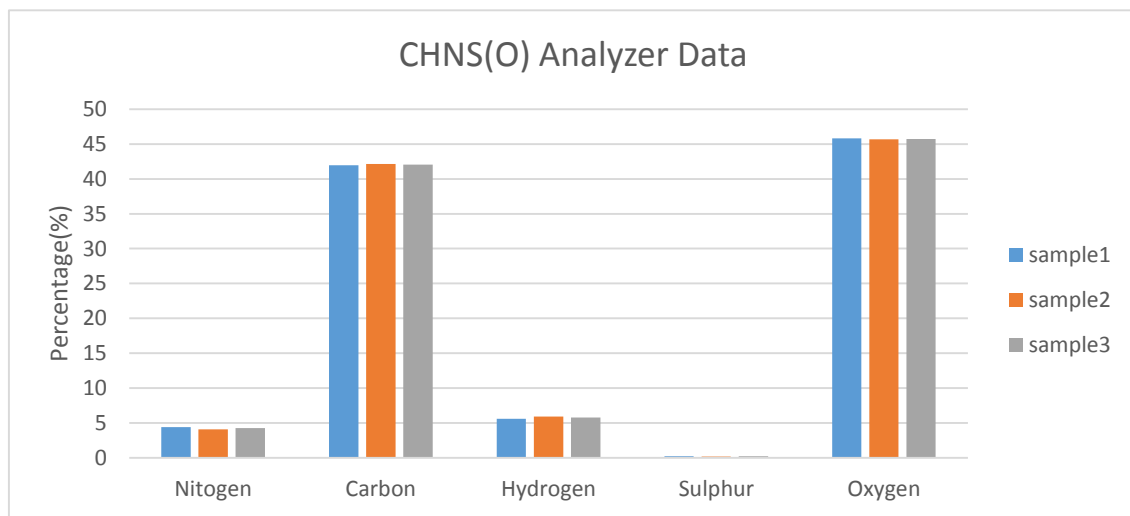

Figure 13 bar graph showing percentage of CHNS (O) in food waste samples

From the data for CHNS(O) percentage in figure 13, average carbon, hydrogen, nitrogen and oxygen percentage was found to be 42 %, 5.75 %, 4.23 % and 45.75 % respectively. These results are very important for calculating the biogas yield of a sample, if the empirical formula for a sample containing carbon, nitrogen, and hydrogen using Buswell formula (Buswell,

1952), is known to us the amount of carbon dioxide, ammonia, and hydrogen sulfide which can be produced after decomposing the sample can be calculated.

4.5 BIOGAS ESTIMATION

On an average 634 kg of food waste is generated in the mess of Vikram Sarabhai Hall. Out of this if only dry waste was taken into consideration that is 184.62 kg.

So on the basis of CHNS analyzer results carbon % in this sample is 42.06% which is equal to 77.65 kg, out of this only 60 % biogas is decomposed which is equal to 46.59 kg converted biogas. (Banks, 2009) From Buswell formula represented in section 3.5 carbon percentage can be calculated. Out of 46.59 kg converted biogas 55 % is methane and 45 % is carbon dioxide. So amount of methane comes out to be 25.62 kg.

Using the ideal gas equation at STP we get 35.87 m^3 of methane so the total biogas volume is 65.21 m^3. Using the calorific value of methane that is 1 m^3 = 10 KWh we can calculate amount of energy in our sample that comes out to be 358.7 KWh.

CHAPTER 5

CONCLUSION

5.0 CONCLUSION

A lot of fuel is utilised to make food for the boarders of Vikram Sarabhai Hall of residence, and food thus prepared has an added value compared to the raw food. Everyday around 600 kg of food waste is generated. This can be put to use by using this food waste to produce biogas. After analysing all the results from a series of experiments it can be deduced that food samples which were collected from the backyard of the mess are rich in carbohydrates and proteins. This food waste generated from hostel mess is a quality feedstock to produce biogas. Most of the waste which is produced is considered to be of no use and hence dumped in the ground which has serious implications like air pollution and soil pollution. The food waste collected has a huge biogas potential and gives a good methane yield. Based on the series of experiments and analysis I would like to propose a biogas plant in the backyard of the hostel. This will certainly help to reduce the LPG consumption in the hostel mess.

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