"OPTIMIZATION OF SUBSTRATE IN ANAEROBIC DIGESTER"

A PROJECT REPORT

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

BACHELOR OF TECHNOLOGY

IN

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Under the supervision of

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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CERTIFICATE

This is to acknowledge that the work presented in this project report titled **"OPTIMIZATION OF SUBSTRATE IN ANAEROBIC DIGESTER"** is done as a part of the award of the degree of Bachelor of Technology, presented to Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is a genuine record of assessment done by **Vibha and Anshul** throughout a period from July,2017 to May,2018 under the supervision of **Dr. Ashish Kumar,** Associate Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date - May, 2018

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ABSTRACT

As the population of the world is increasing rapidly and use of the fossil fuels are increasing greatly. The fossil fuels are limited source of energy and one day they will get extinct. So there is need of some alternative source of energy. Biogas is versatile source of energy and it is one of best method for the production of energy. Our study mainly focuses upon the effective use of waste generated from the food waste for the maximum generation of energy from the biogas. After studying various research papers published on biogas from different wastes example animal manure and food waste information was obtained. This information helped us in several ways like what type of food waste is best for maximum production of biogas.

Main purpose of our project is to study the optimized ratio of substrates that is cow dung and food waste in anaerobic digesters to get maximum amount of biogas. It focuses on the potential of substrates to generate biogas based on their capacity or production. Various tests on the different types of food wastes were performed to know the potential and amount of biogas produced from the food wastes. The pH, temperature and organic loading rates are factors which can affect the production of biogas. This study very useful for successful utilization of food wastes for biogas production which decreases our dependency on LPG which will help in saving energy and cost. Utilization of wastes is important because it is harmful for our environment.

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LIST OF ABBREVIATIONS

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
TOC	Total Organic Carbon
TKN	Total Kjedahl Nitrogen
C:N	Carbon to Nitrogen Ratio
OLR	Organic Loading Rate
FS	Fixed Solids
TS	Total Solids
VS	Volatile Solids
MC	Moisture Content
AD	Anaerobic Digester

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Biogas means a gas which is produced by the method of anaerobic fermentation of organic matters such as fertilizer, food waste, sewage, plant materials and plant residue in absence of oxygen. In fact, biogas is also made from the residue of organic matters from both the ethanol and biodiesel production. The C/N ratio of the material, concentration, pH and temperature plays major role is the production of the biogas. Biogas is composed of methane (CH_4), carbon dioxide (CO_2) and may have small quantity of hydrogen sulphide (H_2S) and hydrogen (H_2). The energy released from biogas that is bio energy can be used as a fuel .It can be use for the purpose of heating and also for cooking in homes and restaurants. It can also be used in a gas engine to change the gas directly into electrical energy and in heat. This is the best technique to manage approximate all organic waste, also digestate is not harmful for environment and can be used as substrate.

Biogas is produced:

1. As landfill gas which is obtained by the decomposition of organic waste inside a landfill due to chemical reaction.
2. As digested gas produced in the digester at anaerobic conditions (absence of air).

1.1.1 Composition Of Biogas:

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 sulfide	H_2S	0–3
Oxygen	O_2	0–0

Biogas typically refers to a combination of different gases produced by the fermentation of organic matter in the anaerobic environment. The conditions within the anaerobic reactor that is temperature, pH in reactor and concentration of substrate varies the composition of biogas. Landfill gas produces methane around 50-55%.By the advanced waste treatment method methane can be produced around 55-75%, which for reactors with free liquids can be improved to 80-90% methane by in-situ gas purification methods. Biogas also contains some other gases carbon dioxide (CO_2) around 25-50%, nitrogen (N_2) 0-10%.It also contain some traces of ammonia (NH_4) and hydrogen sulphide (H_2S).

Methane is the essential component in biogas which is responsible for the energy. Methane is a flammable gas. Carbon dioxide (CO_2) is the second most essential component.

1.2. Indian Scenario of Biogas

Biogas plants in rural areas are based on domestic animals dung and food wastes for heating and lighting purposes. A household type biogas plants produces the biogas from organic matters such as cow dung and other bio-degradable substances, for example biomass from gardens, kitchens, farms etc. The method of biogas generation is called anaerobic digestion. The following are advantages of the Biogas technology:

1. Chemical manure should be possible away with since the processed slurry got from the biogas plants can be utilized as advanced bio-fertilizer.
2. It is useful for the environment and for sanitation issues since toilets can be connected specifically with biogas plants.
3. It provides clean fuel for cooking purpose.

1.2.1 Biogas Production in India:

1. In 2014-2015, around 20,700 lakh m^3 of biogas is generated in the India which is equal to 4 to 5% of the LPG use in the nation.
2. Bio-fuels are probably going to contribute 5000 MW to the overall renewable energy target of 175,000MW by 2022.

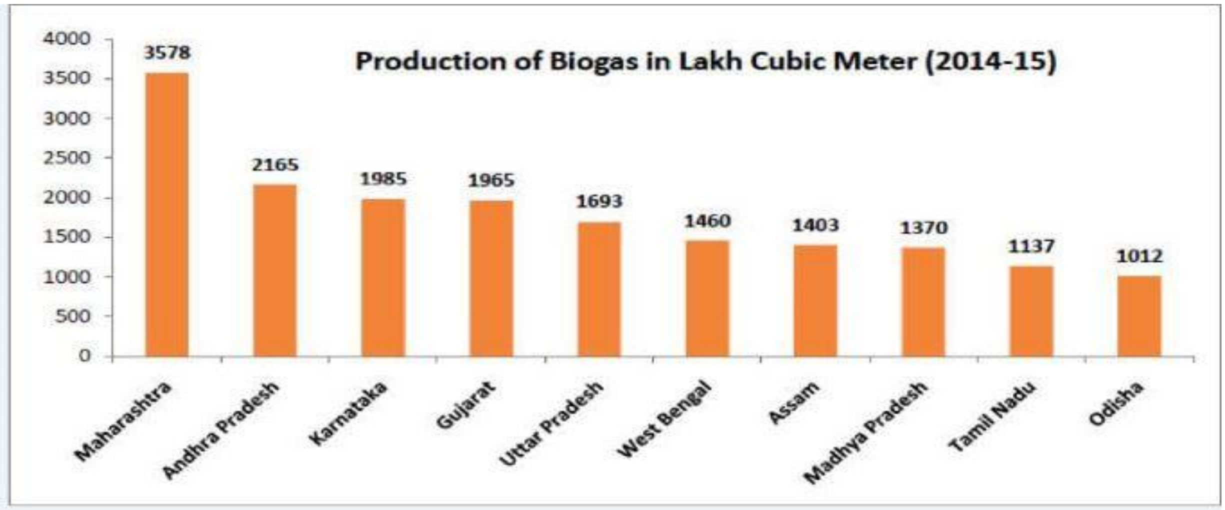

Fig1.1: Production of Biogas in Lakh cubic Meter (2014-15)

1.3 Global Scenario of Biogas

Biogas is versatile source of energy. In comparison to other energy sources, it can be converted to the liquid, gaseous and solids fuels. Bio energy can be utilized for electrifying the homes, heating and fuelling in vehicles. Globally, bio energy accounted for 15% of the world's energy consumption in 2012 with approximately 2.6 billion people dependent on traditional biomass for needs. The consumption of bio energy varies geographically.

In the world USA and the Brazil are the leading producer and consumers of the bio fuels for transport. In the Americas production of bio fuels increased from 16 billion liters in 2000 to 79 billion liters in 2012. The biomass utilization for electricity is well-known in Europe and America mostly produced from forest residues. The Europe and Americas continent contribute above 71% of all use of biomass for electricity. 462 TWh of electricity was produced in all over the world from biomass in the year 2013. Biomass is considering increasing uptake in rising nations in Asia and Africa where major population lacks access to electricity. Biogas systems are becoming more cost competitive. Cogeneration plants using agricultural residues in India are successful. Biomass has been the most important source of energy for heating. Currently biomass in the form of heat is mainly use in developing countries and rural areas.

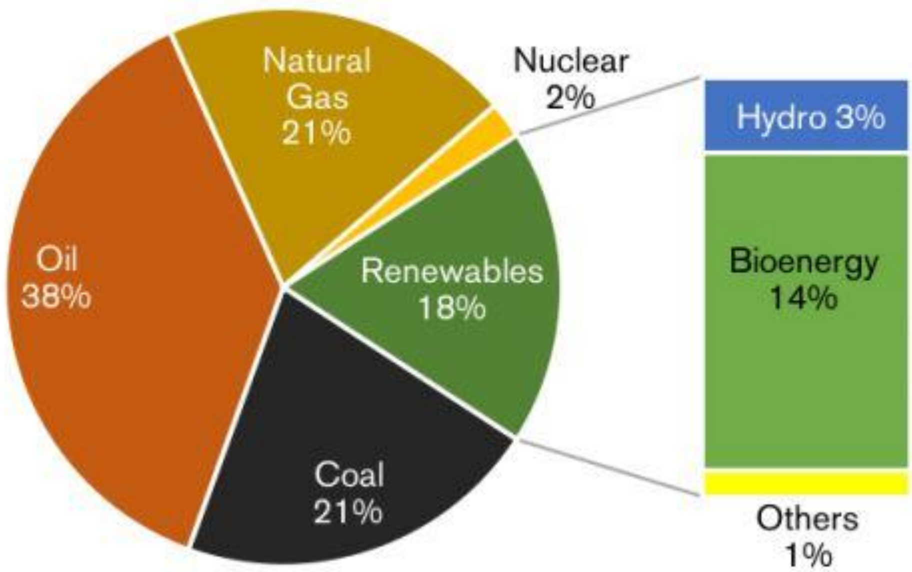

Fig 1.2: In 2013 Global energy consumption

1.4 Biogas Advantages and Disadvantages

1.4.1 Advantages of Biogas:

1. The biogas is less in cost and it is most economical technology for the heat and electricity generation.
2. Biogas plants require low capita investment. Biogas plants can be easily set up at homes.
3. Biogas is clean, non polluting source of energy. It is also sustainable source of power and it reduces the emission from greenhouse effect.
4. Jobs are created in rural areas for millions of people in the biogas industry.
5. It can be compressed into the natural gas and utilized as power in vehicles.

1.4.2 Disadvantages of Biogas:

1. Biogas plants are not economical for the big scale use. For the big scale use it also requires large area.
2. Complete refining is not possible of biogas still it contains many impurities and it can sometimes corrode the engines of automobiles when used as fuels.
3. In the cold climate biogas production is very less because the biogas generation is highly dependent upon temperature.

1.5 Anaerobic Decomposition

Anaerobic digestion is process in which the microorganism at anaerobic conditions decomposes biodegradable materials. This process of decomposition of organic matter is biological process. As a result of this degradation methane (CH_4), carbon dioxide (CO_2) and small amounts of gases like H_2, H_2S and NH_3 are also formed. Anaerobic digestion takes place in four different stages. Theses stages are as follows:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

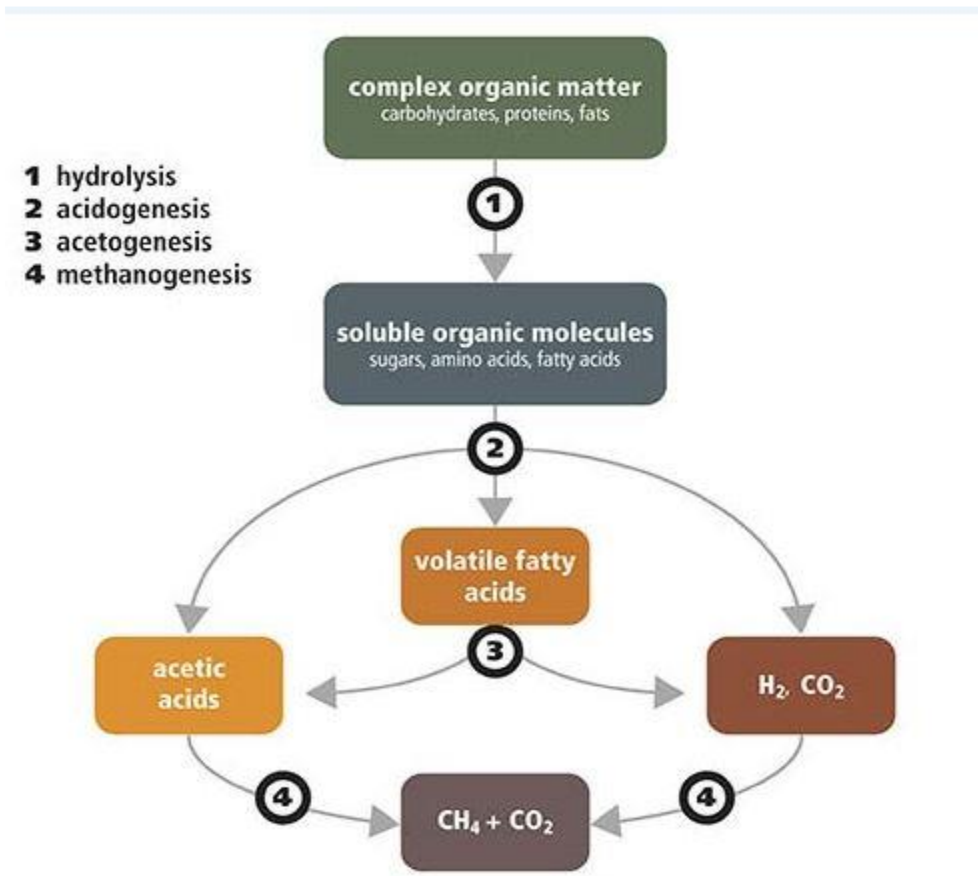

Fig1.3: Anaerobic Digestion Process

1. **Hydrolysis:** It is the process of degradation of large complex organic matter into smaller units. Complex organic matter like carbohydrates, proteins and fats breaks into smaller constituent parts which are sugars, amino acid and fatty acids. Hydrogen and acetate in this stage is used by methanogens. Bacteria responsible for breaking of large matters into smaller units are hydrolytic or facultative anaerobes. This process of breaking of large chains into smaller matter is called hydrolysis.
2. **Acidogenesis:** Further degradation of the residual components in the hydrolysis stage by fermentative (acidogenic) bacteria takes place in this stage. Volatile fatty acids (VFAs) along with the carbon dioxide (CO_2), ammonia (NH_3) and hydrogen sulphide (H_2S) are formed in this stage.

3. **Acetogenesis:** The next step of digestion is acetogenesis. Further digestion of simple molecules created from the acidogenesis stage takes place by acetogens to produce the acetic acid (CH_3COOH), carbon dioxide (CO_2) and hydrogen (H_2).
4. **Methanogenesis:** This stage is very essential for the production of the methane. Methanogens converts the intermediary products of previous stages into the methane carbon dioxide and water. Methanogenesis takes place at pH 6.5and 8.

1.5.1 Factors which influence biogas production

1. **Alkalinity and pH:** Alkalinity is important for the proper control of pH. Alkalinity prevents the rapid change in the pH. Methanogens microorganisms grow below pH of 6.2. Methanogens performs better in pH ranges 6.8 to 7.2. Biogas is influenced by pH. Due to the production of volatile acids the pH in the digester firstly will reduce. However, as methane-forming (methanogens) bacteria consume the volatile acids and alkalinity is produced in the anaerobic digester, the pH of the digester increases and then stabilizes. Anaerobic digester is stable when there is high alkalinity concentration.
2. **Temperature:** The role of temperature is very significant in the biogas production. Biogas production is mainly dependent upon the temperature. The methanogens are not active at very high or very low temperatures. The optimum range of the pH for biogas is around 35^{o}C. Production of the gas stops when the temperature goes below 10^{o}C .So insulation is provided in the digester in cold region for the production of gas.
3. **C/N Ratio:** Maximum digestion in the digester occurs at the C/N ratio 30:1 and gas production is more at this ratio. When the C/N ratio is not proper digestion and gas production is less.
4. **Loading Rate:** Loading rate also effects the gas production. Loading rate is the quantity of raw matter fed per unit volume in the digester per day. If the feeding in the digester is more acids will accumulates and it inhibited the methane production.

1.6 Food Waste generated

Excess waste of food produced can cause environment pollution. Large quantity of methane is produced in landfills by food waste which is more influential greenhouse gas than carbon dioxide (CO_2). These greenhouse gases present in excess amount such as methane, carbon dioxide and chloro fluorocarbons (CFCs) absorb infrared radiation and heat the earth atmosphere which cause global warming and climate change. According to the survey of the **United Nation Development Programme 40**% of the food produced in India is wasted. In India around 21 million tons of wheat is wasted. According to the ministry of agriculture every year in India about ₹50,000 core of food produced is wasted. 25% of fresh water used for the preparation of food is finally wasted, even as of many people still do not have water for drinking.

1.6.1 Consequences of Food Waste:

1. Excess of the food waste can decrease the fertility of the soil. It makes the soil unfertile because food waste contains many hazardous substances.
2. When food waste is buried in the soil there is emission of the toxic gases.
3. Emission of green house gases which can cause global warming.
4. Food waste also contaminates the river water and ground water.

1.6.2 Solutions:

The solution to these problems of pollution, contamination, leaching is waste management. Waste management is technique for managing waste materials in the most effective and efficient manner so as not to cause any harm to environment and other beings. This involves collecting, transporting, treating and then finally disposing the waste under constant monitoring. However, management means how you can use waste and convert it into something valuable. The waste can be thrown in trash, dumped, treated or recycled depending on the type of the waste.

There are many techniques in which waste is managed most common being composting, recover, incineration, recycle, landfills, converting waste to energy etc. Some of these ways can be practiced at home like reuse and recycle which will decrease the quantity of material disposed.

1. **Compositing:** Compositing is a natural process of degradation of organic matter. This process involves degradation of plants, kitchen and garden wastes into material that is rich in nutrients and act as food for plants. It is used in organic farming where these organic materials are left at a place for months till the bacteria degrade and decompose it. This is best waste management methods so far. These were the advantages of this method but it also has a disadvantage of taking time and space.
2. **Recover and Recycle:** Recover refers to using the beneficial disposed items for other use. These disposed off items then undergo processing to extract materials or convert them into sources of energy in the form of electrical energy and heat etc. Recycling involves consumption of waste products and converts them into new products. This technique avoids usage of energy and new raw materials to produce the same. Other advantages are reduction of water, air pollution, greenhouse gas emissions, energy usage and preservation of natural resources for sustainable future use. Disadvantages include unhygienic, unsafe recycling sites.
3. **Incineration:** In this method the waste materials are burned in high temperatures which convert them into gaseous form. One of the greatest advantages of this technique is that the reduction in volume is 70 to 80 percent of the original volume of waste, thereby reducing the space acquired. This is also known as thermal treatment as the waste materials get transformed into ash, heat and steam. This method is used in various countries where the space availability is very less. Disadvantage is that combustion of wastes lead to air and water pollution and also generation of greenhouse gases.
4. **Landfills:** The most popular method nowadays is disposal in landfills. This deletes the odour issues as the waste is buried into the ground and also reducing the dangers of waste materials. But this method needs space for disposal and therefore it now becoming less popular because of less space availability. Another drawback is presence of methane and other gases in landfill which can contamination of soil, land, surroundings, water which will further contaminate water bodies and plants where this

water will discharge. It also cause air and water pollution which can become fatal to animals and human beings.

5. **Waste to Energy Conversion:** This process involves conversion of non-recyclable waste into energy in the form of electricity, heat and fuel after undergoing various processes. Moreover, this is a renewable energy source as the non-recyclable waste can be used repeatedly to generate energy. This is a sustainable technique as this would involve utilizing waste to produce energy rather than fossil sources**.** Composting and anaerobic digestion is so far the best method of waste management. This method solves the problems of high amounts of waste generation, causing less pollution, tackling the energy crisis by generating energy from the waste itself and saving on other raw materials and fossils.

1.7 OBJECTIVE

Although a lot of work has been done in this field, using different combination of substrates but we are doing work on Pine needles and Food waste as substrates. Our motive is to optimize the ratio of substrates that should be taken such that it results in maximum biogas production. The process is for waste generated such that it can be utilized reducing the waste management problems in our country. Here, we are optimizing OLR.

This process also comes with limitation of temperature. Temperature should be maintained for the gas production, ideal temperature for mesophilic is $35^{0}C$-$40^{0}C$ and for thermophilic is $50^{0}C$-$55^{0}C$, but we are doing our work in hilly areas where temperature is low. As the process is sensitive to temperature, we are studying the effect of low temperature on the production. Also, in hilly areas Pine needles are available in excess, sometimes causing forest fires, so we are checking whether it can be utilized or not solving this issue as well.

CHAPTER 2

LITERATURE REVIEW

2.1 General

To present the work done and the project work on the biogas and other factors related to the work objective, various literature writings on research work done in this field were collected and evaluated. This involves gathering of data and materials on the topic, along with journal articles, research papers, outlines and technical details assembled by the research organizations and government department. The review is associated with studying these papers and then reviewing them based on personal understanding.

The current study is based on:

1. Characterization of substrate i.e. food waste and cow dung

2. Study on the comparative behavior of cow dung and Co-digestion of cow dung with food waste.

2.2 LITERATURE REVIEW ON BIOGAS PLANT IN JUIT CAMPUS

Tripathi,A.K et al. (2015) led the study on productivity of biogas by utilizing pine needles assimilated with wastewater of sewage. The work was studied for small capacity plant installed in Juit. Different models studied were Fixed dome, Floating Drum, Flexi type out of which Fixed type was popular and rest were rejected due to failure and technical reasons. Cellulose in needles was higher than 51%, making it perfect for production of energy. The compact plant is appropriate in rural areas of hilly regions where population is scarce.[1]

Devi, R. et al. (2016) studied the biogas production capacity of pine needles to be used as substrate in batch digesters. Two digesters were setup where in digester 1 cow dung was fed and in digester 2 cow dung and pine needles were fed in and studied for the identical conditions in field. These were analyzed for factors like BOD, COD, TS, VS reduction before and after digestion. As the campus is in hilly area, where temperature is less with fluctuations and therefore its consequences were studied which is a major parameter in the production of biogas.[2]

2.3 LITERATURE REVIEW ON BIOGAS PRODUCTION USING SUBSTRATES

Agrahari R.P. et.al., (2013) conducted an attempt to study the behavior of different kitchen waste ratios. The setup used was a floating type aluminum plant with slurry space of 31kg.This metal increase the inner temperature of digester. Kitchen waste is effective in saving LPG by energy generation as easily get decayed by bacteria. Solar radiation affects the temperature which in turn affects the gas production. Assessment of various ratios of the waste was done to find the best optimized ratio leading to highest rate of production.[3]

Dioha I.J. et.al., (2013) assessed the impact of carbon to nitrogen ratio on the generation of biogas. Factors influencing the production were analyzed and studied and the results showed that the optimum range of C:N ratio is 25-30 which regulates the pH of slurry . Slurry was prepared by mixing sun dried cow dung with water in a flask and then kept airtight. Nitrogen and carbon content was then checked showing cow dung has the potential to generate maximum yield.[4]

Agrahari R.P. et.al., (2013) conducted a semi-continuous study on the utilization of greenhouse chamber for generation of biogas by increasing the temperature at the time of winters. Aluminum made chambers of biogas was used outside and inside the greenhouse canopy. Ratio of water to kitchen waste taken was 3:1, with initial pH at the time of inserting of 7.2. The production rate outside of chamber was less as the temperature was low, while it was more with high methane fraction of 51% inside of chamber due to high temperature reflecting that temperature plays a major role in the formation of biogas. In addition to greenhouse setup to increase the temperature, other options are also available like using aluminum plant or coating with black paint to increase the heat absorption from sunlight.[5]

Vaid V. et.al., (2013) led a study on biogas as a fuel and a renewable energy source. Food was used as a source of fuel wherein the food having high calorific value led to higher volumes of methane formation. It has lower lignin and higher water content making it perfect for digestion. Calculations showed various parameters such as calorific value of biogas as 21.6 kJ/L in comparison to that of LPG having calorific value of 94kJ/L and density of 0.557kg/L. Further calculations estimated that the numbers of LPG cylinders which can be saved daily from one 1000L digester are 6 contributing a huge amount of fuel conservation. Thus, food waste is a sustainable way to tackle the waste disposal and energy issues.[6]

Riar N. et.al., (2013) reviewed the problems of waste generation and disposal, and the effectiveness of this technique to reduce the waste thereby generating heat and energy using Deenbandhu biogas plant. Slurry was prepared by mixing cow dung and water in ratio 1:1, in 20 liter tank. Kitchen waste was collected from dustbin, and then was crushed into pieces to obtain better digestion. Initially, the production was less as bacteria utilized the waste more quickly leading to decrease in pH of the waste. Some microorganisms like methane microorganisms are sensitive to changes in temperature; therefore temperature should be kept stable. Optimum range for production of biogas is 35^{o}C-45^{o}C which should be maintained inside the digester. This method of utilization of kitchen waste is an eco-friendly, renewable and cost efficient with investment cost of Rs 27000 and also don't require too much space of 424sq.ft.[7]

Beedu R. et.al., (2014) led a study on production of biogas using food waste with the process of anaerobic digestion. A uniform mixture was prepared in batches where 10kg cow dung was mixed with 15 liters of water. To check the production, gas burner was ignited and methane was indicated by the blue colored flame. Blended and crushed food showed more gas generation than when they were fed without any crushing. Underfeeding as well as overfeeding should not be done as former would decrease the efficiency and latter would increase the pH thereby decreasing the metabolism and amount of gas formation. Therefore, conclusion was made that food waste can be used as an effective replacement of LPG.[8]

Wang X. et.al., (2014) studied the performance of substrates used i.e. chicken manure, rice straw and dairy manure in anaerobic co-digestion. Batches were prepared by combination of all substrates in ratios such that C:N becomes 25 and also tested for varying ratios at mesophilic and thermophilic temperatures. Results showed that methane content increased and then decreased with increase in C:N. Optimum C:N came out to be 26.76 at 35^{o}C and 30.66 at 55^{o}C. Ammonia did not show hindering effects under the thermophilic temperatures which may due to correct C:N ratios, which suggested that it is necessary to optimize C:N ratio to avoid ammonia hindrance. Modifying the substrate proportions to obtain desired characteristics like C:N, pH, nutrients is a successful way to obtain the desired results.[9]

Deressa L. et.al., (2015) did a consistent study of utilizing mixture of fruit, vegetable waste and cow dung as input in the digester. Various parameters of total solid, moisture content, volatile solids and ash content were also tested. For performing this experiment, 80L digesters and 2L bottles were taken as digesters. Wastes were collected from various locations like juice shop, university cafeteria and ranch. Slurry was prepared in the ratio 1:5 by weight and fed daily for 5 days. Reduction in TS/VS resulted in high biogas production leading food waste to become effective renewable source of energy.[10]

Musa B. et.al., (2016) led a study on analysis of organic wastes i.e. cow dung, goats droppings and chicken droppings. Digesters of 6.5 liters capacity were filled by water and substrates with their ratio being 1:4. They were placed at ambient temperatures. The substrates were tested for different parameters of pH, temperature with the HRT and loading rate kept fixed. Chicken droppings produced highest volume of gas wit least flammability. Cow dung similarly produced less than chicken droppings and greater than goat droppings. Also, cow dung was most flammable followed by goat dropping. This study led to the finding that animal waste was undesirable for the environment and could be used as a way to meet urban and rural energy needs.[11]

CHAPTER 3

EXPERIMENTAL SETUP AND METHODS

3.1 GENERAL

This chapter explains the experimental setup and methods that are done and followed in the project work based on our objective and also the characterization of substrates i.e. cow dung and food waste. Physiochemical characterization was found out based on a series of tests and were also compared on before and after digestion basis. Rate and amount of biogas and methane production was also measured and recorded continuously. Tests were performed on batches to analyze the generation in all the digesters. Temperature was kept constant as the digesters were kept in an incubator but pH was measured regularly and in another they were kept in ambient conditions. The biogas was measured by the water displacement method and methane content using sensor. The setup and methods used has been explained thoroughly here.

3.2 DESCRIPTION OF THE SETUP

This section describes the substrates used, materials fed, and the digester used for the experimental works.

3.2.1 Design 1

Digesters used were inverted floating type digester where 3 digesters AD1, AD2 and AD3 were setup. AD1 consist of 100% cow dung, AD2 consist 100% food waste and AD3 consist 50% cow dung and 50% food waste. Cow dung was used as inoculum in add three digesters in addition with 1.5 litres of sewage water from nearby biogas plant. The capacity of the container was 60 litres with height of 45 cm and inverted bucket of 20 liters with height 35 cm. The fitting consist of ½ inch tank connection nipple, ½ inch valve, ½ inch nipple and gas cork. The digesters were kept for a period of 60 days. They were kept outside the Fluvial Hydraulics Laboratory in the Civil Department of Jaypee University of

Information Technology, Waknaghat (H.P) so as to keep them exposed to sunlight and were covered with a green cover to enable the setups to absorb more heat.

Fig3.1: Digesters of design1

3.2.2 Design 2

In this design twelve batch digester bottles were setup in an incubator at 30^{o}C. Here the temperature is kept controlled. Bottles used were of 1litre capacity where in digesters 1 to 6 cow dung was fed and in 7 to 12 cow dung and food waste was fed. Water was used as inoculum and filled up to 700ml mark. Cork was fitted in all the bottles and drip was inserted in them as a pipe. Another setup prepared consists of a container to hold water, a cylindrical measuring cylinder fitted with a pipe (drip) at the bottom.

Fig3.2 Digesters in Incubator at 35^{o}C

Fig3.3: Water displacement setup

3.3. DETAILS AND SOURCE OF SUBSTRATES

This study focuses on the co-digestion of cow dung and food waste along with their capacity to produce biogas and methane. The sewage water used as inoculum was brought from the already running biogas plant in the campus of our university. So the substrates were accumulated according to their ease of convenience. Food waste was taken from the mess of the university continuously for six days and pine needles were brought from the jungle in the campus.

3.3.1. Food waste

Food waste was brought from the students mess in the campus as some amount of food gets thrown there also and we have collected our samples from the accumulated food such as rice, chapatis, fruit peels, radish, cucumber, vegetables etc. Then the waste was accumulated continuously for 6 days and once daily during breakfast, lunch as well as dinner time. It was collected in bags and stored daily in the refrigerator which is present in fluvial hydraulics lab in the civil department to keep the food fresh for usage at the time of input. After 6 days the food was mixed together and then grinded in the mixer to fine particle size. Grinding the substrate leads to higher production of biogas as more area is exposed and accessible for the microorganisms to attack upon and thereby giving good results. Then the food was fed in required quantities in desired ratios.

Fig 3.4: Crushed food waste

3.3.2. Inoculum

It was brought from the biogas setup in the campus of university. Here the plant is a inverted floating type digester where 2 plastic tanks are used. Here digester has volume capacity of 1000 liters and inverted holder of 750 liters volume capacity. For our setup of previous work done we have taken 1.5 liters of inoculum in three bottles for every digester. The inoculum acts as an accelerator for the digestion activity as the microbes in it are in large amounts and they cause the decaying of substrates quickly. It helps in this procedure by digesting them quickly and producing more biogas.

3.3.3. Cow Dung

It was brought from a village some distance away from the university. The material brought was fresh and stored in refrigerator to keep it fresh. The quantity of feed was more in previous work as the setup was larger in size than the next work. In the previous work, cow dung was also utilized as inoculum with a quantity kept fixed in all AD's so that differentiation can be done and impact of substrates can be measured. In the next work, only cow dung was input in some bottles and in some both was input again to compare their performance. It is wealthy in nitrogen, potassium and minerals enabling the growth of microbes to produce more biogas with higher methane fraction. The availability of this substrate is easy and due to it's properties, it has proved to be an effective material for our objective.

Fig 3.5: Cow Dung fed in digester

3.4 SUBSTRATE CHARACTERISTICS DETERMINED

Various physio-chemical properties in substrates were found out which are necessary for our work and to analyze and get an account of it much better. For design 1, pH, TS, VS, C/N, TOC, alkanity, COD, temperature were found and concluded whereas for the design 2, pH, alkanity and BOD were found out. The need of doing these tests is that they reflect the substrate potential in different fields on the basis of which trait is in that substrate. For our work, it helps to analyses and generates a comparison among each other making it possible to conclude which substrate is more efficient in producing biogas. Thus, it becomes necessary to find them to get the best output and usage.

3.5 METHOD FOLLOWED

In both the designs, setup that has been used is batch anaerobic digesters with the difference in their sizes and quantity of matter that is fed in. Three and six digesters were used in both designs to check for their behavior and capability to give desired output.

3.5.1 DESIGN 1

In design 1, three digesters were setup namely AD1, AD2 and AD3 which were plastic buckets with inverted small size bucket to hold the gas formed. In AD1, only cow dung was put precisely 3kg of cow dung with 1kg extra which was kept constant and fed in all the setups used as inoculum. In AD2, 3kg food waste was fed with 1kg inoculum and in AD3, 1.5kg food and 1.5kg cow waste was put with 1kg of inoculum. To all the digesters, 1.5litres of wastewater from biogas plant was also fed. The bucket capacity was 60 litres so to fill upto the top 32 litres of water was added in all of these leaving some head space. Initial and final characteristics of the samples were found to make comparison and find the best ratio that is generating the biogas. Temperature and pH were measured consistently and volume of gas formed was also marked and measured. The retention time was 60 days with ambient temperature low in the winter season.

3.5.2 DESIGN 2

In design 2, twelve digesters were setup but the digesters in this design were glass bottles of 1litre. To them, gas cork was fitted with a hole drilled in them to which drip was inserted and fixed. This served as the pipe medium to transfer the gas formed at the time of measurement. Initially, drips were closed to prevent any leakage. To this cow dung was put in first six bottles in varying quantities and in next six food and cow waste was put again in different ratios. Food was first crushed in grinder before feeding. This helps to analyse which ratio gave best result. Then water was added upto 700ml mark leaving 300ml as the head space for the gas formed. The bottles were then kept in incubator at 30^{o}C for the entire period of 30 days. pH and gas was measured consistently and tests like alkanity, BOD were performed on samples before and after their digestion.

3.6 TESTS PERFORMED ON SAMPLES

3.6.1 pH test

pH meter is used for the measuring the pH of digesters.

3.6.2 Alkalinity test:

Procedure

1. Take a 100 ml samples in separate conical flask.
2. One drop of Sodium thiosulphate solution of 0.1N (normality) is added to completely removal of free remaining chlorine.
3. Add two drops of phenolphthalein indicator. If the colour of samples turns to pink titrates it with 0.02N sulphuric acid (H_2SO_4) till colour turns from pink to colourless.
4. Note down the volume of H_2SO_4 added (V_1).
5. Add two drops of methyl orange indicator is added when there is no change in colour after adding of phenolphthalein. Then yellow colour appears in sample.
6. Then titrate with H_2SO_4 solution having normality 0.02N. Titrate until the colour of the samples changes to pink.
7. Note down the readings of H_2SO_4 added (V_2).

8. Calculate the alkalinity by formula:

$$\frac{\textbf{V} * \textbf{Normality of sulphuric acid} * \textbf{1000} * \textbf{500}}{\textbf{volume of sample}}$$

Fig 3.6: Titration to check the Alkalinity

3.6.3 Temperature:

Temperature of digesters was collected on daily basis. Temperature readings were noted using manual glass thermometer.

Fig 3.7: Manual glass thermometer

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

Procedure

1. Take 20ml of each sample in 3 separate dishes and weigh them.
2. Put the samples in the oven and set temperature at 105^0C and we get total solids.
3. After 24 hours weigh the samples and note the readings.
4. Then the same samples were taken and put in muffle furnace at 600^0C for 2 hours.
5. Weigh the samples and we get fixed solids and lost solids are volatile solids.

3.6.5 Total Organic Carbon Estimation:

Procedure

1. Take 1 g of sample from each digester and dry for 15-20 minutes at 100 °C in oven.
2. Weigh 0.05 g from dried sample and put into a 250 ml flask.
3. 10 ml of Potassium Dichromate (K_2CrO_7) having normality 1N is added.
4. Add 20 ml quantity of sulfuric acid (H_2SO_4) and mix it for 60 seconds.
5. Wait for cooling of flask.
6. Add 200 ml of distilled water for dilution.
7. Phosphoric acid of 10ml, Sodium fluoride of 0.20g, and 10 drops of diphenylamine used as indicator is added.
8. Titrate the sample against 0.5N ferrous ammonium sulphate till the turbid blue color appears.
9. Add the titrating solution drop by drop until the end point is reach.
10. When the color turns to a green.
11. In same manner blank sample is prepared.

Fig 3.8: TOC Testing

3.6.6 Total Kjeldhal Nitrogen Estimation:

Procedure

1. Take samples and oven dry it at 100-105°C for 10-15 minutes.
2. In the Kjedhal flask transfer 2.0gm of dry sample.
3. Add 0.3g of Copper Sulphate ($CuSO_4$), 10g of Potassium Sulphate (K_2SO_4) and 30ml of Sulphuric acid (H_2SO_4).
4. Digest the mixture over heat for 4 hour until the initial black color turned bluish green.
5. In a round bottom flask collect the content and add 50% NaOH which change the color from bluish green to blackish brown.
6. Distilled it by using steam in a Kjeldhal assembly and sthis distillate is collected in a 200ml of H_2SO_4 having normality 0.1N.
7. Determine the remaining H_2SO_4 by titration against 0.1 N NaOH, using phenolphthalein as the indicator.

8. Calculate the Nitrogen content by formula:

$$\frac{(\mathbf{200} - \mathbf{litre}) * \mathbf{0.14}}{\mathbf{weight\ of\ the\ sample\ in\ grams}}$$

Fig 3.9: TKN Testing

3.6.7 BOD

Procedure

1. Dilute 2ml of sample with the 398ml of distilled water.
2. Fill it in the BOD bottles.
3. Note down the dissolved oxygen (DO) readings with the help of the DO meter.
4. Keep the BOD bottles in the BOD incubator at 20^{o}C
5. Keep the bottles for 5 days in incubator.
6. After 5 days again measure DO with the help of DO meter.

7. Then BOD is calculated by formula :

$$\frac{(\textbf{zero day D.O} - \textbf{5 days D.O})\ \textbf{x 200}}{\textbf{volume of sample}}$$

Fig 3.10: BOD Incubator

CHAPTER 4

CALCULATIONS AND RESULTS

4.1 RESULTS FOR DESIGN 1:

4.1.1 pH Test:

A continuous monitoring of pH has been done throughout the experiment. The pH was found in the range of 6.5-7.5; 5.5-7.0 and 5.5-7.2 for Design 1, 2 and 3, respectively (Table 4.1). However, the observed pH was not found in an optimum range, the effect of which can be seen on methane generation.

Table 4.1: pH readings in digesters

Day	Digester 1	Digester 2	Digester 3
1	6.5	5.5	5.7
2	6.5	5.5	5.8
3	6.7	5.6	5.5
4	6.4	6.0	6.0
5	7.0	5.8	6.2
6	7.1	6.1	6.5
7	7.5	6.2	6.3
8	7.4	6.3	6.7
9	7.0	6.3	6.8
10	7.1	6.3	6.8
11	7.1	6.5	7.1
12	7.5	6.4	7.1

13	7.5	6.7	7.2
14	7.5	7.0	7.2

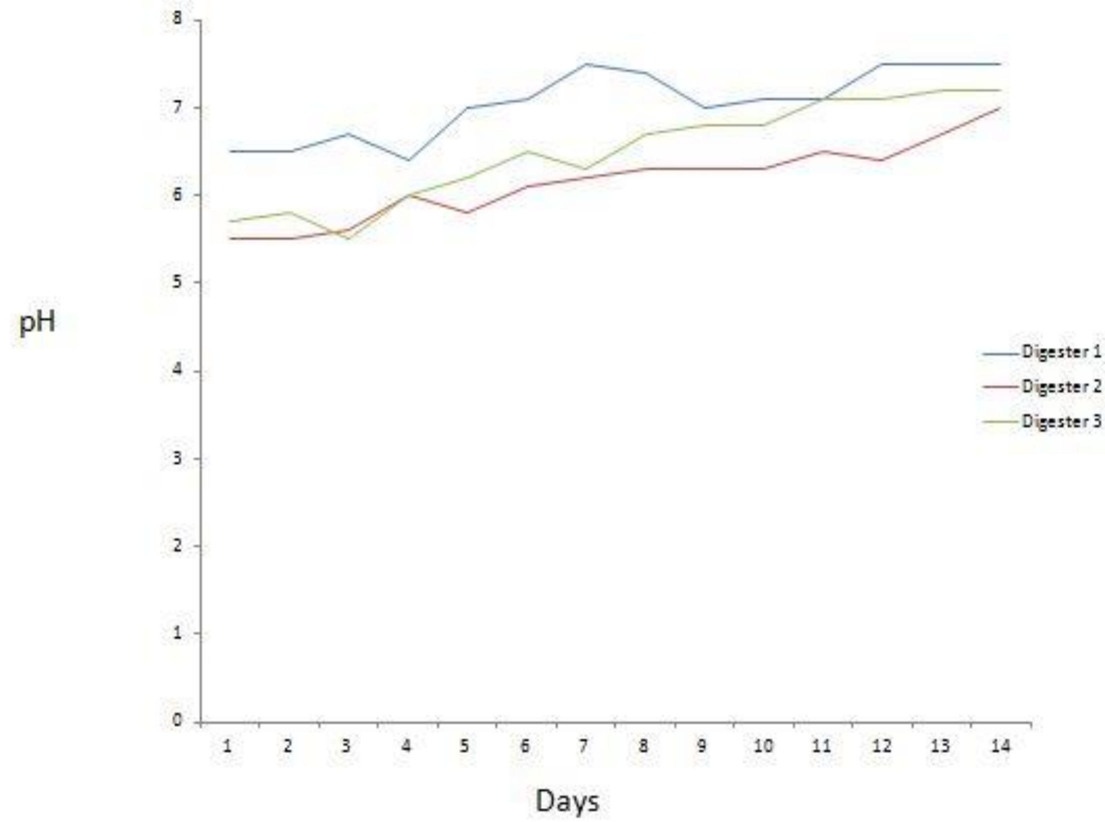

Fig 4.1: Variation of pH with time

4.1.2 Temperature

During the anaerobic digestion temperature plays a significant role. It has a decisive role during the methanogenesis process. The optimum temperature for methane production is reported 30-35°C. However, in this experiment temperature has varied continuously and not found in the optimum range.

Table 4.2: Temperature readings in digesters

Day	Digester 1	Digester 2	Digester 3
1	17	18	17
2	17	18	18.2
3	16	15.9	15.9
4	14	15	16
5	15	15	15
6	12	12	12
7	14	14	13.8
8	11	11	11
9	12	12	12
10	12	11	12
11	13	13	12
12	14	15	19
13	13.5	13.5	17
14	15	14	19

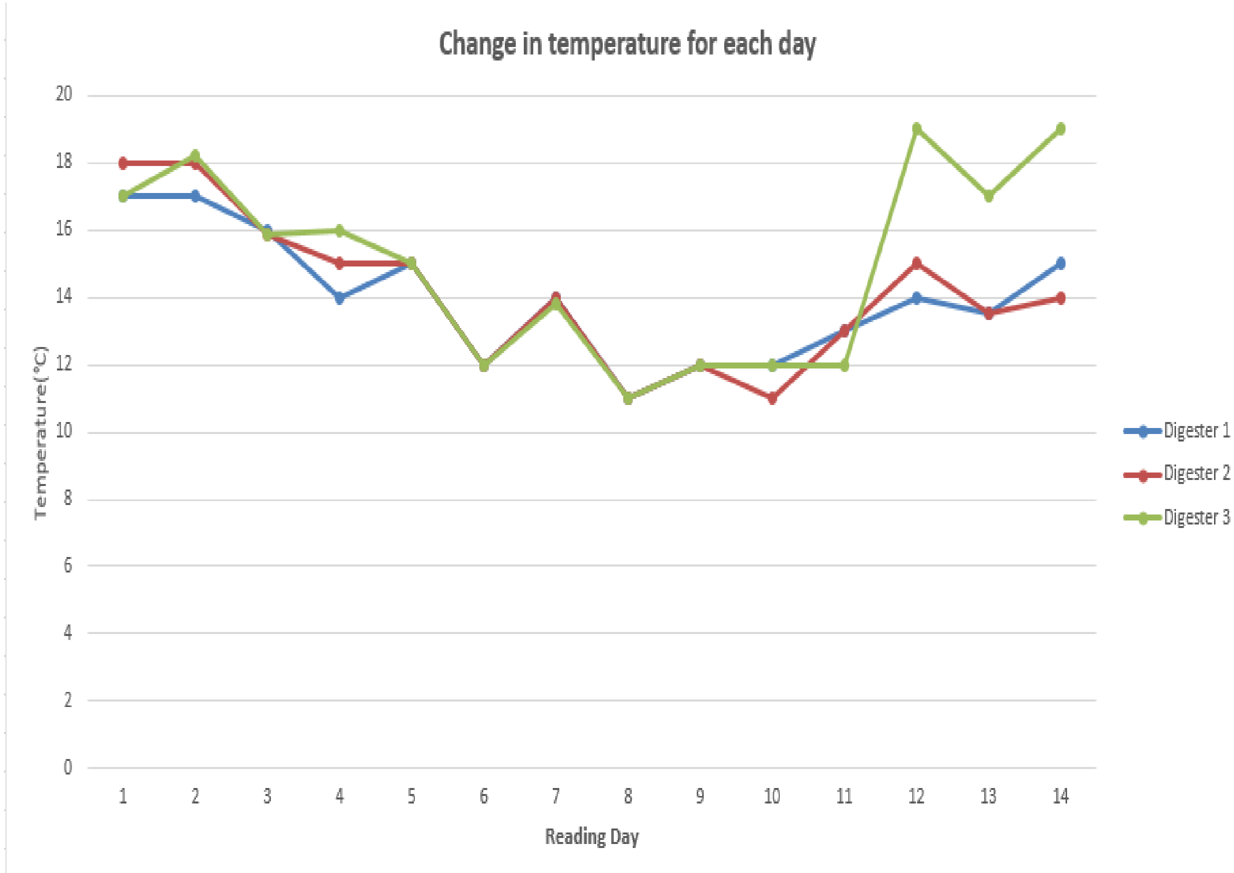

Fig4.2: Variation of Temperature in digesters

4.1.3 Characterization of Substrates

Various parameters such as TS, VS, pH, TKN, C/N has been done. It is found that VS/TS ratio was reported 94.47, 82.56 and 59.9% for food waste, cow dung and inoculum, respectively. The lowest pH was reported for food waste, however cow dung was reported with optimum pH range.

Table 4.3: Substrate Characterization

Parameters	Food Waste	Cow Dung	Inoculum
TS(%)	18.1%	15.6%	3.118%
VS(%)	17.1%	12.88%	1.87%
Ph	6.5	7.1-7.4	6.7
VS/TS	94.47%	82.56	59.9%
TOC(%)	46.67%	18.7%	22.7%
TKN(%)	3.54%	1.2%	-
C/N Ratio	13.2	15.74	-

4.1.4 Alkanity:

Alkalinity can be defined as buffering capacity for any anaerobic digestion system. During the Digestion complex material break downs into small molecules, during that process formation of VFA take place. As the VFA start accumulating in the digester pH of the system start falling down hence, methanogenesis process inhibit. At that time if alkalinity of the system is not enough, system cannot recovers its pH. However, alkalinity of the system was found in the optimum range in all the digesters.

Table 4.4: Alkanity of samples

Digester	Alkanity(mg/L)	
	Before Digestion	**After Digestion**
AD1	1387	2727
AD2	920	2667
AD3	1050	2056

4.1.5 Chemical Oxygen Demand (COD):

COD is a parameter which tells about Organic and Inorganic potential of the substrate. However, inorganic fraction of the substrate cannot be utilized for digestion. Form Table 4.5, it can be seen that COD of all the digesters have reduced after the digestion. Highest COD reduction has been reported for the AD3.

Table 4.5: COD of samples

Digester	COD(mg/L)	
	Before Digestion	**After Digestion**
AD1	150000	97500
AD2	2200	1540
AD3	73600	54464

4.1.6 Biogas Generation:

Measurement of biogas for all the digesters has been done for 45 days. From Fig 4.3 it can be seen that the lag phase of 5, 8 and 10 days were reported for AD3, AD2 and AD1 respectively. Digesters-3 has yielded more than that AD2 and AD1.

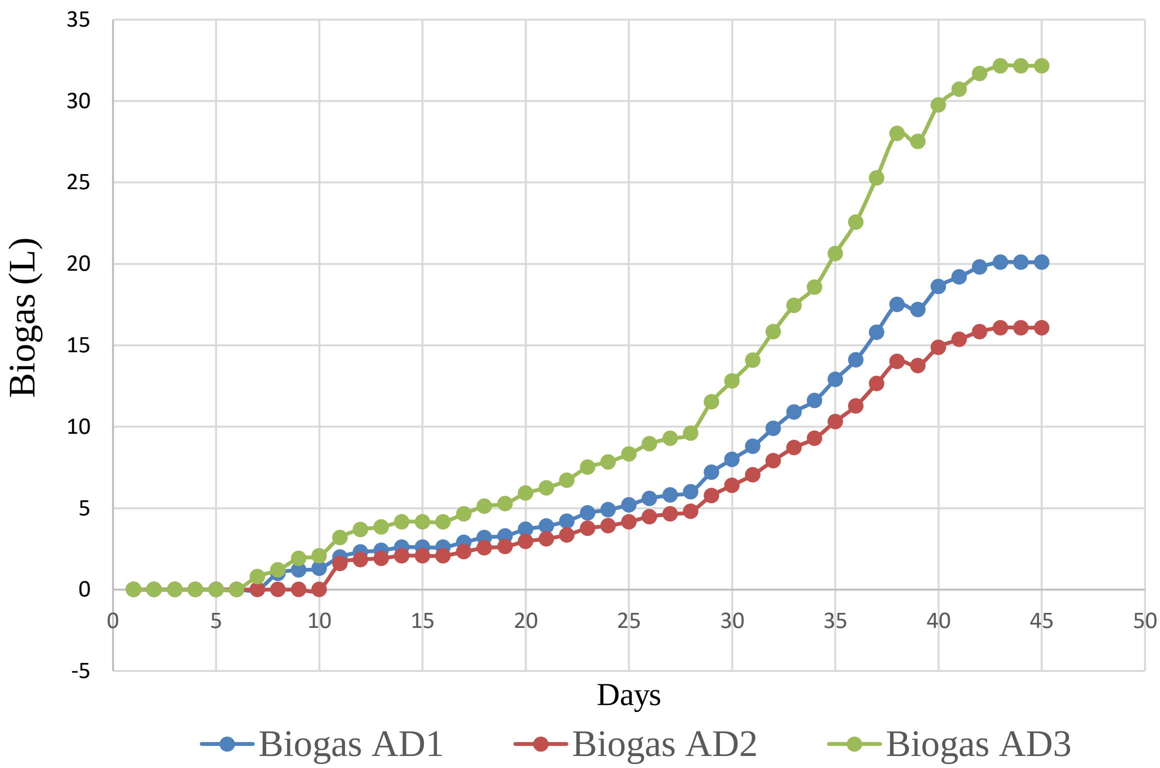

Fig 4.3: Biogas variation in digesters with time

4.1.7 Methane generation:

A similar behavior was found for methane generation as it was found in biogas generation. AD3 has reported highest methane yield in comparison to the AD2 and AD1. Therefore, it can be concluded that co-digestion has yielded in highest energy recovery. Apart from that, it is surprisingly noticed that AD1 has recorded highest methane i.e. 68% (Table 4.6)

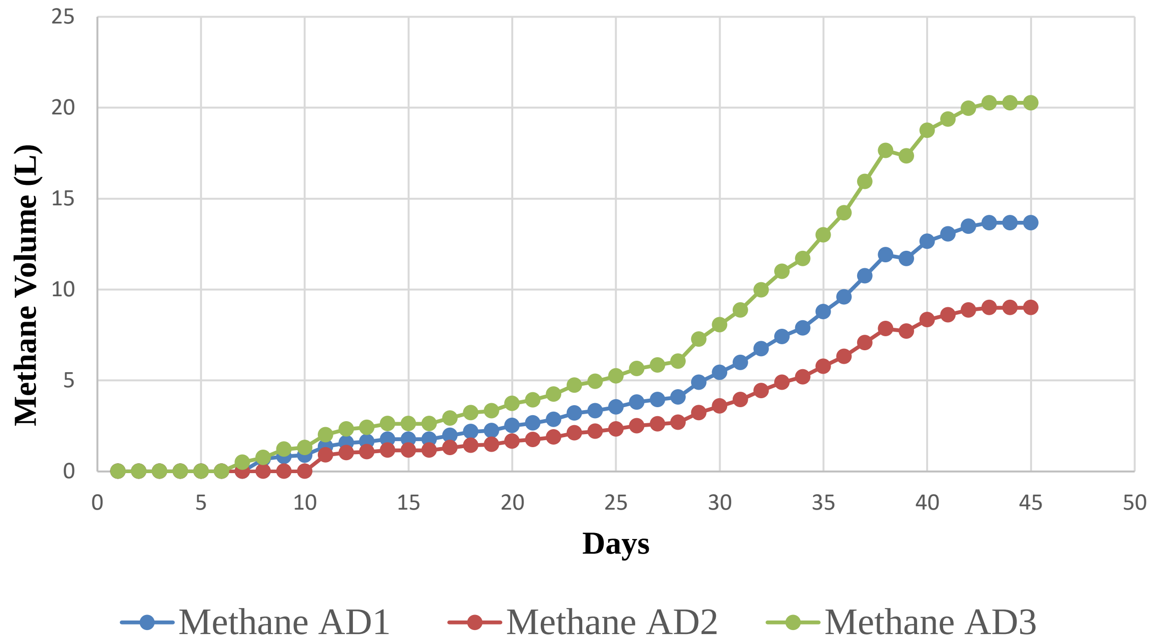

Fig 4.4: Methane variation in digesters with time

Table 4.6: Average Methane percentage

Digesters	Average Methane production
AD1	68%
AD2	56%
AD3	63%

Fig 4.5: Recorded methane percentage

4.2 RESULTS FOR DESIGN 2:

4.2.1 Characterization of substrates:

Table 4.7 Substrate Characterization

Parameters	Food Waste	Cow Dung
TS	28.276%	14.9%
VS	13.254%	12.32%
TOC	45.7%	18.5%
MC	71.723%	58.34%

4.2.2 pH:

From the Table 4.8 it can be seen that initially pH of all the digesters were not in optimum range. However, with the passage of time pH of all the digesters reduced gradually and met to the optimum.

Table 4.8: pH readings in digesters

Digester	DAY 1	DAY 15	DAY 20	DAY 30
1	8.2	7.2	6.9	6.2
2	8.1	7.3	6.8	6.1
3	8.1	7.3	6.7	6.1
4	8.2	7.2	7.1	6.3
5	8	7.4	6.9	6
6	8.1	7.3	6.8	6.1
7	8.3	7.4	6.8	6.2
8	8.3	7.2	6.9	6.3
9	8.1	7.3	6.9	6.2
10	8.1	7.2	6.9	6.3
11	8.1	7.3	6.8	6.1
12	8.1	7.3	6.9	6.2

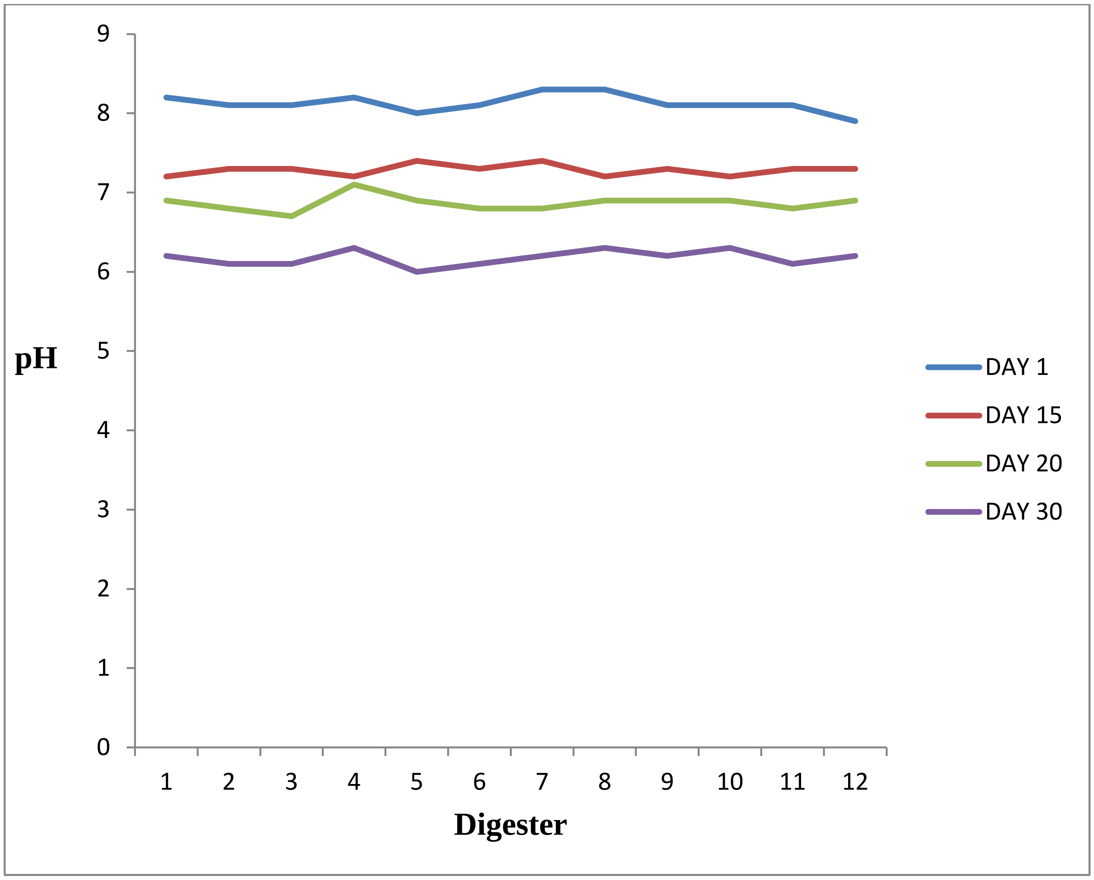

Fig 4.6: pH variation with time

4.2.3Alkanity:

Table 4.9: Alkanity of samples

Digester	**Alkanity (mg/L)**	
	Before Digestion	**After digestion**
1	850	1578
2	859	1586
3	864	1595
4	878	1599

5	888	1642
6	890	1634
7	915	1661
8	925	1662
9	937	1670
10	967	1689
11	979	1702
12	980	1721

4.2.4 Biogas Formation:

Table 4.11: Biogas formation in digesters in (mL)

Digester	DAY 1	DAY 15	DAY 20
1	0	30	80
2	0	100	100
3	0	25	30
4	0	145	110
5	0	140	210
6	0	90	150

7	0	75	130
8	0	190	135
9	0	165	120
10	0	160	165
11	0	330	350
12	0	255	355

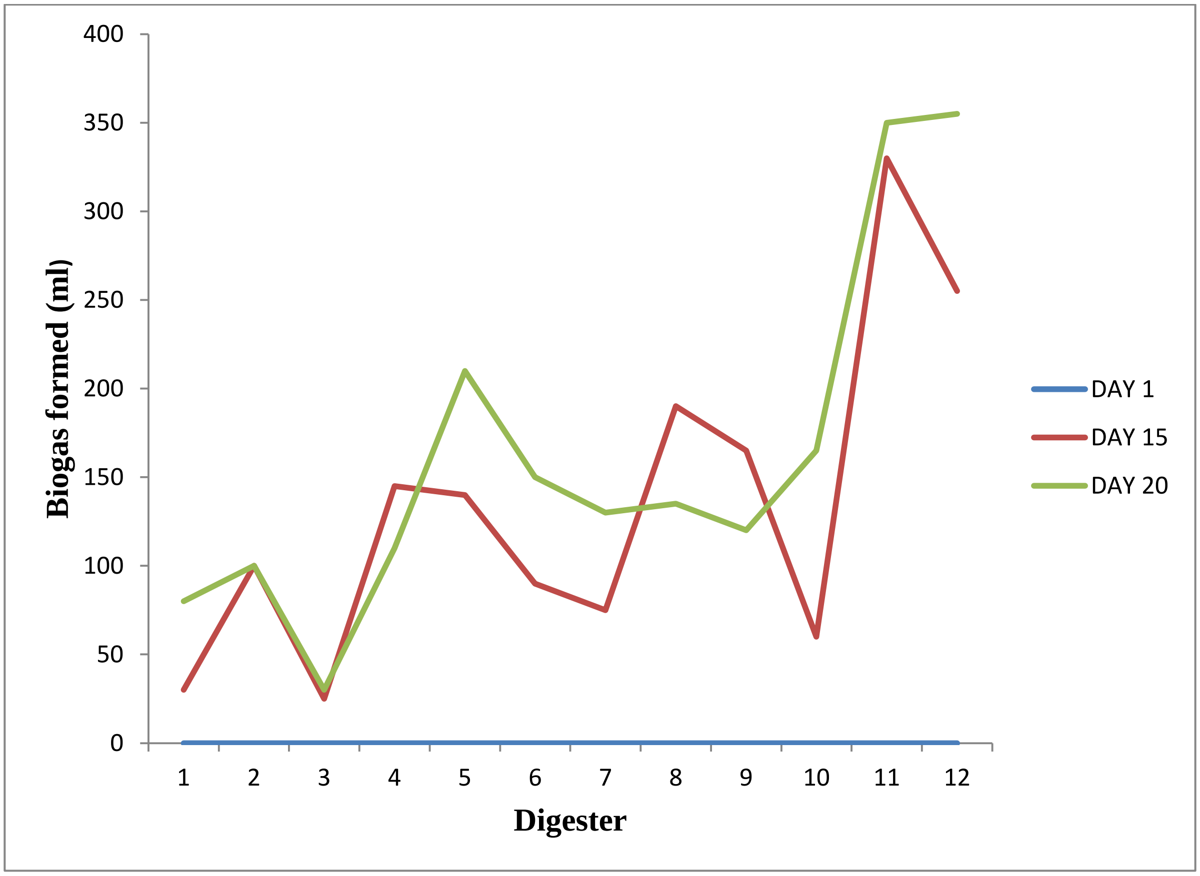

Fig 4.7: Biogas variation in digesters with time

CHAPTER 5

CONCLUSION

5.1 GENERAL

Based on our observations and results gathered after necessary calculations, the substrates used by us came out to be useful and effective in generating biogas. The amount of gas formed showed a rise in volume on the basis of variation of quantities that was fed. Two things were accounted i.e. quantity of biogas formed and percent of methane in it.

The materials that were used in our study were brought from the campus itself as they were easily present in or nearby the university. The food was brought from the mess in the campus, cow dung brought from nearby village, inoculum from a plant similar to ours present in the campus. Thus there were no issues in arranging these materials and making the accumulation part very easy for our study.

Therefore, it is recommended to co-digest food waste and cow dung for future usage as the results showed sufficient gas production with methane fraction that satisfies the required range. This method also contributes to the waste management, its efficient utilization and solving disposal scenarios.

SUBSTRATE CHARACTERIZATION:

1. Substrates are tested for parameters like pH, TOC, BOD, temperature and C:N ratio content.
2. TS fraction is higher in food than cow manure and least in inoculum and similar is the case with VS fraction in both of them. The fraction depends on the water present in them.
3. TOC percent is also more in food as it has more carbon and organic content as compared to cow manure.
4. This also accounts for C:N ratio more in cow dung by calculating from TOC and TKN values.

5.2 DESIGN 1:

1. AD1 showed pH in range of 6.4-7.6, which is in near neutral range as it contained only cow dung which itself has pH almost in neutral range. Lowest values were reflected in AD2 because of food more by weight and AD3 had intermediate values as it has same weight of food and cow manure.
2. Temperature in all AD's are low as the location of our work is hilly terrain, therefore it influences the result. More gas will be produced if temperature would have been high.
3. Alkanity in AD1 showed most value as the nature of its materials are near to neutral range and also the values rose after digestion as the nature also shifted to neutral alkaline side.
4. Since the average methane production is in range of 56-68%, therefore co-digestion of the substrates gives the desired results and should be adopted for future times.

5.3 DESIGN 2:

1. pH readings are in the range of 6-8.4 which is slightly more than the optimum range and then decreased to the required range after some days from which the production of biogas also started. Temperature was kept constant at 30C as the bottles were kept in the incubator for the entire period of retention.
2. Alkanity values increased from the bottles with cow dung to the ones with both food waste and cow manure. The bottles in which food was put more had more alkanity which is also affected by pH.
3. The BOD showed rise from bottles with cow dung to the bottles with food and cow dung. This is due to the fact that food contains more organic fraction due to which the biochemical demand is more in digesters with more food weight.
4. Biogas formation started from day 7 and highest gas volume was measured in digester 10 and 12 on the 15th day because food was co-digested with cow dung. On the 20th day, digester 8 and 12 produced most volume of biogas which shows that when food is co-digested with cow dung gives best outcomes.
5. Thus both the substrates can be surely used as substrates and a good tool for the trash management.

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