VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JnanaSangama, Belagavi – 590018

A Project Report
On

"Investigation on Improving Biogas Production Rate and its Properties from Different Biomass Samples"

Submitted in partial fulfillment of the requirements as a part of the curriculum,

Bachelors of Engineering in Mechanical Engineering

Submitted by

Prajwal.M.C
(1CR17ME414)

Carried out at
CMR Institute of Technology

Under the Guidance of

Narendra.N
Assistant Professor
Department of Mechanical Engineering

Department of Mechanical Engineering
CMR INSTITUTE OF TECHNOLOGY
132, AECS Layout, Kundalahalli, ITPL Main Rd, Bengaluru – 560037

2019-20

CMR INSTITUTE OF TECHNOLOGY

132, AECS Layout, Kundalahalli colony, ITPL Main Rd, Bengaluru-560037

Department of Mechanical Engineering

CERTIFICATE

Certified that the project work entitled **"Investigation on Improving Biogas Production Rate and its Properties from Different Biomass Samples"** is a bonafide work carried out by **Mr. Prajwal.M.C,** bonafide students of **CMR Institute of Technology** in partial fulfillment for of the requirements as a part of the curriculum, **Bachelors of Engineering in Mechanical Engineering,** of **Visvesvaraya Technological University, Belagavi** during the year **2019-20**. It is certified that all correction/suggestion indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the bachelor of engineering degree.

(Mr. Narendra.N)	**(Dr. Vijayanand Kaup)**	**(Dr. Sanjay Jain)**
Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**

External Viva

Name of the examiners	**Signature with date**
1.	
2.	

DECLARATION

We, students of Eighth Semester, B.E, Mechanical Engineering, CMR Institute of Technology, declare that the project work titled **"Investigation on Improving Biogas Production Rate and its Properties from Different Biomass Samples"** has been carried out by us and submitted in partial fulfillment of the course requirements for the award of degree in **Bachelor of Engineering in Mechanical Engineering** of **Visvesvaraya Technological University, Belagavi,** during the academic year 2019-2020.

Mr. Prajwal.M.C
(1CR17ME414)

Place: Bengaluru
Date:

ACKNOWLEDGEMENT

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible, whose constant guidance and encouragement crowned the efforts with success.

We would like to profoundly thank **Management** of **CMR Institute of Technology** for providing such a healthy environment for the successful completion of Project Work.

We would like to express our thanks to the Principal **Dr. Sanjay Jain** for their encouragement that motivated us for the successful completion of Project Work.

It gives us immense pleasure to thank **Dr. Vijayanand Kaup** Professor and Head of Department for his constant support and encouragement.

Also, we would like to express our deepest sense of gratitude to our Project Work guide **Mr. Narendra.N** Assistant Professor, Department of Mechanical Engineering for his constant support and guidance throughout the Project Work.

We would also like to thank the Project Work Coordinator **Mr. Prashant.S.Hatti** Assistant Professor, Department of Mechanical Engineering and all other teaching and non-teaching staff of Mechanical Engineering Department who has directly or indirectly helped us in the completion of the Project Work.

Last, but not the least, we would hereby acknowledge and thank our parents who have been a source of inspiration and also instrumental in the successful completion of the Project Work.

- Prajwal.M.C

ABSTRACT

As we know the renewable energy source are depleting day by day, hence there is necessary to search for alternative fuel in which Biogas can be taken as new source of energy, Biogas can be generated from different natural resources there is necessary for us to find the effective composition of biomass mixture to have maximum production rate, Methane content and Calorific value, so that it can be used instead of fossils fuels. A description of the evolution of the studies is presented, culminated with the biomass analysis till analyzing of generated Biogas which is thoroughly described, from the conception process to the final proposed solution.

In our research we have tried out different combination of biomass mixture which has cattle manure, silkworm larva litter, vegetable and kitchen waste feed for co-digestion in to a anaerobic digester and we are also finding out reason for maximum content of methane, calorific value in a particular combination.

We have observed the 10% cow dung + 30% water + 10% urea+ 50% silk worm larva litter give us the better results with total biogas produced for 15 days was 0.6821 with methane content 63.22% of biogas generated and a calorific value of 6005 kcal.

TABLE OF CONTENT

1. **INTRODUCTION** 01
   - 1.1 BRIEF INTRODUCTION 01
   - 1.2 CHARACTERSTICS OF BIOGAS 03
   - 1.2 PRODUCTION PROCESS 04
   - 1.3 BIOGAS PLANTS 07
   - 1.4 DEVELOPMENT AROUND THE WORLD 11
   - 1.5 ADVANTAGES, BENIFITES AND APPLICATION OF BIOGAS 18
2. **LITERATURE SURVEY** 22
3. **METHODOLOGY** 28
   - 3.1 ANALYSIS OF BIOMASS SAMPLES 28
   - 3.2 BIOGAS PRODUCTION 29
   - 3.3 BIOGAS ANALYSIS 31
4. **RESULT AND DISCUSSION** 34

CONCULSION 49

REFERENCES 50

CHAPTER 1

INTRODUCTION

1.1 BREIF INTRODUCTION

The global energy demand is growing rapidly, and about 88% of this demand is met at present time by fossil fuels. Scenarios have shown that the energy demand will increase during this century by a factor of two or three (IEA 2006). At the same time, concentrations of greenhouse gases (GHGs) in the atmosphere are rising rapidly, with fossil fuel-derived CO_2 emissions being the most important contributor. In order to minimize related global warming and climate change impacts, GHG emissions must be reduced to less than half of global emission levels of 1990 (IPCC 2000). Another important global challenge is the security of energy supply, because most of the known conventional oil and gas reserves are concentrated in politically unstable regions [1].

The availability of conventional fuel resources, increase in fuel cost and the increasing concern for environmental issues have challenged researchers to develop new techniques to obtain clean and sustainable energy through the utilization of renewable energy sources. Biogas technology introduces a very attractive way to utilize biomass sources for fulfilling partial energy requirements. Biogas system can provide multiple benefits to the users and can protect the environment [2].

The global energy potential of virgin biomass is very large. It is estimated that the world's standing terrestrial biomass carbon (i.e., the renewable, above-ground biomass that could be harvested and used as an energy resource) is approximately 100 times the world's total annual energy consumption. The largest source of standing terrestrial biomass carbon is forest biomass, which contains about 80 to 90% of the total biomass carbon. Interestingly, marine biomass carbon is projected to be next after the forest biomass carbon in terms of net annual production, but is last in terms of availability because of its high turnover rates in an oceanic environment [3].

Conventionally, biomass is harvested for feed, food, fiber, and materials of construction or is left in the growth areas where natural decomposition occurs. The decomposing biomass or the waste products from the harvesting and processing of biomass, if disposed on or in land, can in theory be partially recovered after a long period of time as fossil fuels. The energy content of biomass could be diverted instead to direct heating applications by collection and combustion. Alternatively, biomass and any wastes that result from it's processing or consumption could be converted directly into synthetic organic fuels if suitable conversion processes were available [3].

Currently, about 2.01 billion metric tons of municipal solid wastes (MSW) are produced annually worldwide. The World Bank estimates overall waste generation will increase to 3.40 billion metric tons by 2050. An estimated 13.5% of today's waste is recycled and 5.5% is composted. The report estimate that between one-third and 40% of waste generated worldwide is not managed properly and instead dumped or openly burned [4].

While source reduction and feeding the hungry are necessary priorities for reducing needless food waste, organic wastes are numerous and extend to non-edible sources, including livestock manure, agriculture wastes, waste water, and inedible food wastes. When these wastes are improperly managed, they pose a significant risk to the environment and public health. Pathogens, chemicals, antibiotics, and nutrients present in wastes can contaminate surface and ground waters through runoff or by leaching into soils. Excess nutrients cause algal blooms, harm wildlife, and infect drinking water. Drinking water with high levels of nitrates is linked to hyperthyroidism and blue-baby syndrome. Municipal water utilities treat drinking water to remove nitrates, but it is costly to do so [5].

Organic wastes also generate large amounts of methane as they decompose. Methane is a powerful greenhouse gas that traps heat in the atmosphere more efficiently than carbon dioxide. Given equal amounts of methane and carbon dioxide, methane will absorb 86 times more heat in 20 years than carbon dioxide. To reduce greenhouse gas emissions and the risk of pollution to waterways, organic waste can be removed and used to produce biogas, a renewable source of energy [5].

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint [6].

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. Biogas is produced by anaerobic digestion with Methanogens or anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials. This closed system is called an anaerobic digester, bio-digester or a bioreactor [7].

1.2 CHARACTERSTICS OF BIOGAS

Methane and other additional hydrogen compounds make up the combustible part of biogas. Biogas is a colorless and odorless gas with a boiling point of -162°C and it burns with a blue flame. At normal temperature and pressure, methane has a density of approximately 0.75 kg/m^3. Due to carbon dioxide being somewhat heavier, biogas has a slightly higher density of 1.15–1.25 kg/m^3 [8].

Energy density is 22.35 to 24.22 MJ/m^3. Ignition Temperature is 650˚C. An explosive limit to air is 5% to 10% by volume [11].

Table 1: Composition of biogas [8].

Gas	% age
1. Methane (CH_4)	55 – 70
2. Carbon-di-oxide (CO_2)	30 – 45
3. Hydrogen sulphide (H_2S) 4. Hydrogen (H_2) 5. Ammonia (NH_3)	1 - 2

1.3 PRODUCTION PROCESS

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Conventional anaerobic digestion has been a "liquid" process, where waste is mixed with water to facilitate digestion, but a "solid" process is also possible, as occurs in landfill sites [9].

Anaerobic digestion process is a well understood chemical reaction which occurs in four different stages. They are hydrolysis, Acidogenesis, Acidogenesis and Methanogenesis. The second and third stages are called as acid formation stage and the last stage is called as methane formation stage. The process flow chart is shown in Fig. 1. [2].

1.3.1 Stages in anaerobic digestion [2].

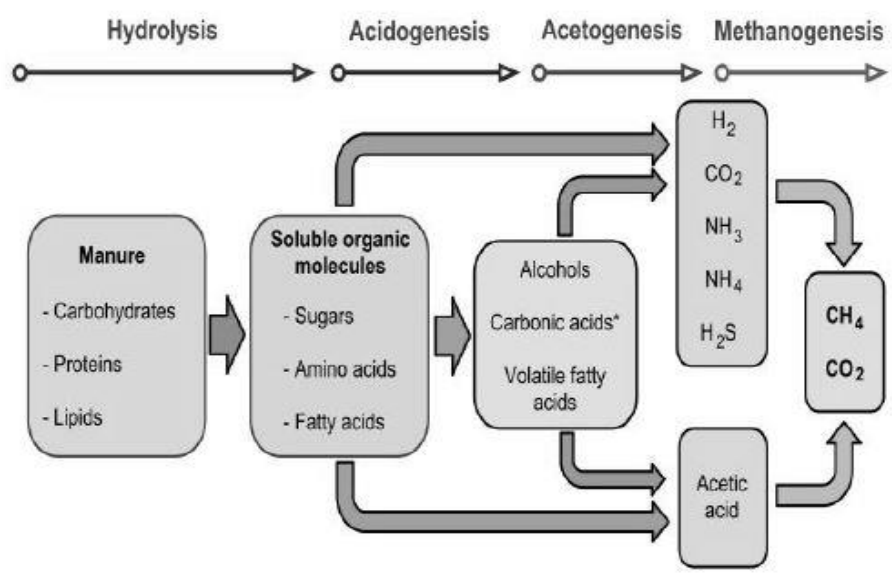


Fig. 1: Flow chart for stages of anaerobic digestion process [2].

Hydrolysis: The first stage in the anaerobic digestion process is hydrolysis. In this stage, the complex organic polymers are converted into simple soluble molecules. During this stage, the lipids (fats) are converted into fatty acids, carbohydrates (polysaccharides) into simple sugars (monosaccharides) and proteins into amino acids. Hydrolysis stage is carried out by different groups of facultative or obligate fermentative bacteria through excreting extracellular enzymes.

Lipases convert lipids to long-chain fatty acids, proteases converts proteins to amino acids and the polysaccharides such as cellulose, starch and pectin are hydrolyzed to monosaccharide by cellulose, amylases and pectinases [2].

Acidogenesis: In the second stage, the soluble compounds produced through hydrolysis are converted into volatile fatty acids (C1-C5), hydrogen, carbon dioxide, ethanol and some organic nitrogen and sulfur compounds. The acids produced in this stage are acetic acid, propionic acid, butyric acid and valeric acid. The acetic acid formed in this stage is directly taken to last stage and the other products are taken to third stage for further degradation by acetogens [2].

Acetogenesis: Third stage of anaerobic digestion process is Acidogenesis. In this stage, the volatile fatty acids having more than two carbon atoms (from Acidogenesis stage) are converted into acetic acids, hydrogen and carbon dioxide with the help of acetogens [2].

Methanogenesis: In the last stage, the methanogenic bacteria (methogens) produce methane by consuming acetic acid, hydrogen and some carbon dioxide. Around 66% of methane is formed from acetic acids by means of acetate decarboxylation and remaining 34% of methane is formed from carbon dioxide reduction [2].

1.3.2 Factors which affect the production of biogas are [10]:

a) Temperature
b) Organic Loading Rate
c) pH Value or Hydrogen Ion Concentration
d) Stirring or Agitation of the Content of Digester
e) C/N ratio

a) <u>Temperature:</u> Internal temperature of the digester greatly affects the production of biogas. The microorganisms participating in the process of anaerobic digestion are divided into three large categories: Psychrophiles (Less than 15^oC) Mesophiles (15^oC – 45^oC) Thermopiles (45^oC – 65^oC). Anaerobes are most active in mesophilic and thermophilic temperature range and hence commonly used temperatures during AD of organic wastes.

b) Organic Loading Rate (OLR): Biogas production is highly influenced by organic loading rate. It indicates the amount of waste that needs to be fed daily. The actual loading rate depends on the types of wastes fed into the digester. The under loading and overloading reduces the biogas production. If OLR is increased, metabolic activity of microorganisms will be high and hence improve biogas yield. A very high value of OLR causes VFA accumulation and accumulation of fine particles which causes membrane fouling and decreased biogas production. Recycling of digested slurry will help underfed digesters to an extent.

c) pH Value or Hydrogen Ion Concentration: pH is one of the main operational factors that affect digestion process. During Anaerobic digestion, there are various micro organisms that require different optimal pH value. It depends upon the temperature maintained inside the digester. Compared to without adjustment of pH, biogas production improved by nearly 67% when pH was adjusted. The optimal value of pH which maximizes biogas production lies in the range 6.5 to 7.2.

d) Stirring or Agitation of the Content of Digester: Stirring or agitation is done to make sure that the contact between substrate and microorganisms are intimate and hence result in enhanced degradation rate of substrate. It is not essential but always advantageous. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of biogas. Biogas production enhanced by about 62% compared to the gas production without agitation.

e) C/N ratio: Relationship between carbon and nitrogen present in organic materials is expressed as C/N ratio. Benefits of nitrogen present in feedstock are: (a) It is an essential element for synthesis of amino acids and proteins; (b) It will be converted to ammonia which helps to maintain favorable pH conditions for microorganisms. Too much nitrogen will cause toxic effect and too little nitrogen cause nutrient limitation. The optimum value of C/N ratio lies between 20 and 30. C/N ratio varies depending on the type of substrate, trace elements and biodegradability. Table 1 shows the C/N values of different substrates.

1.4 BIOGAS PLANTS

A typical biogas system consists of the following components:

1. Digester.
2. Gas holder.
3. Gas pipe, valves and fittings.

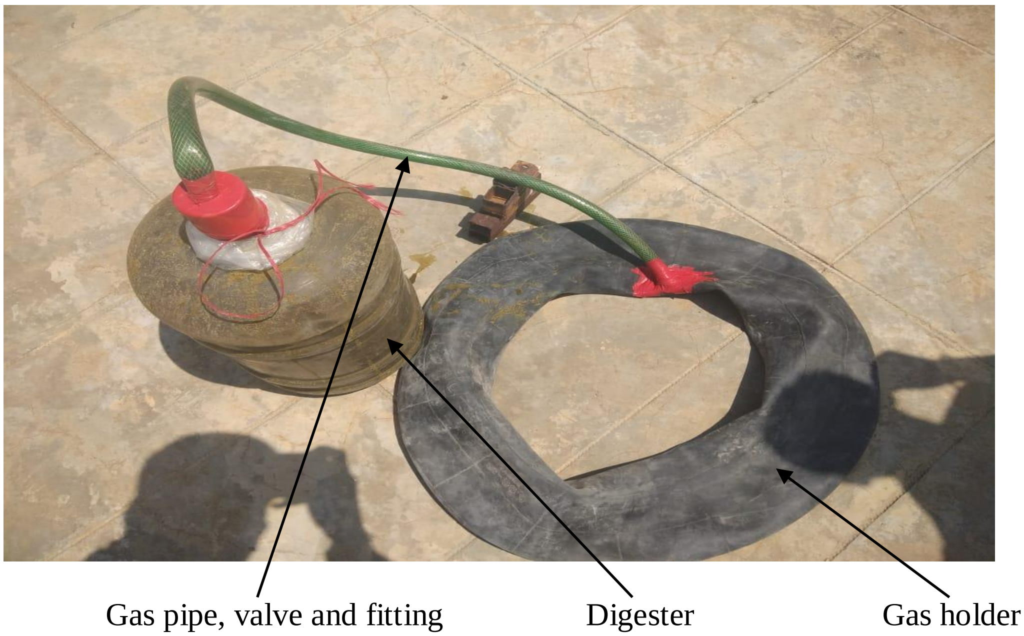


Fig. 2: Typical Biogas Plant.

Choosing a right biogas digester is a very important while constructing a biogas plant. From the stand point of fluid dynamics and structural strength, an egg-shaped vessel is about the best possible solution. This type of construction, however, is comparatively expensive; therefore, its use is usually restricted to large-scale sewage treatment plants [12].

1.4.1 Types of biogas plants [11].

Biogas plants are mainly classified as:

1. Batch feed
2. Continuous feed
   a) Floating drum (constant pressure) type,
   b) Fixed dome (constant volume) type

1.4.1.1 Batch feed biogas plant: This type of plant requires feeding in every 50 to 60 days gap. After feeding 8 to 10 days are required to supply the gas and continuously for 40 to 50 days till the process of digestion is completed and after sometimes it is emptied and recharged. The Battery of digesters is charged and emptied one by one to maintain a regular supply of gas through a common gas holder. The installation and operation of these types of plants are capital and labor intensive. They are non-economical unless operated on the large scale. These types of plants are mainly installed in European countries as they do not suit the condition in Indian rural areas [11].

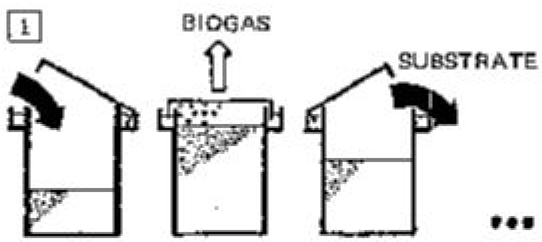


Fig. 3: Batch feed biogas plant [13].

1.4.1.2 Continuous feed biogas plant: This type of plant requires daily feeding with a certain quantity of biomass. The gas is stored in a plant or the separate gas holder and is available for further use. The biomass when slowly passed through digester gets completely digested, and digested slurry is given out through an outlet. The period in which the biomass remains in the digester is known as retention period. This period mainly depends on the type of biomass and operating temperature. The plant is continuously operated and stops only for removal of sludge i.e. undigested biomass residue. The thin dry layer formed at the top of the slurry is known as scum. The function of scum is to prevent the escape of gas from the slurry. The breaking down of layer takes place when the slurry is slowly stirred, and it also helps in digestion process due to better mixing. The feeding pattern of such plants matches with daily waste generation and does not require its storage; therefore they are convenient for individual owners. These types of plants are mainly popular in India and China [11].

a) **Floating drum type of biogas plant (Constant Pressure):** Khadi Village Industries Commission India develops a domestic biogas plant. In this plant, a mild steel drum is used as a gas holder. This drum is most expensive component in this plant and covered by masonry construction with a partitioning wall that creates a required condition for the growth of acid formers and methane formers. This plant produces a good biogas yield [11].

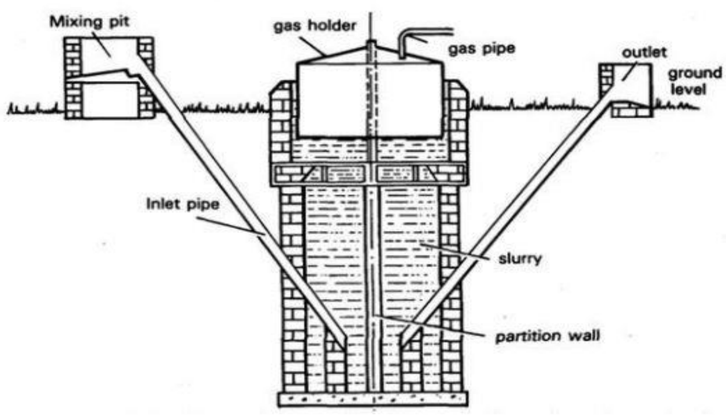


Fig. 4: Floating drum type of biogas plant [14].

<u>Types of floating drum type biogas plant [12].</u>

- KVIC model with a cylindrical digester, the oldest and most widespread floating drum biogas plant from India.
- Pragati model with a hemisphere digester
- Ganesh model made of angular steel and plastic foil
- Floating-drum plant made of pre-fabricated reinforced concrete compound units
- Floating-drum plant made of fiber-glass reinforced polyester
- low cost floating-drum plants made of plastic water containers or fiberglass drums: ARTI Biogas plants
- BORDA model: The BORDA-plant combines the static advantages of hemispherical digester with the process-stability of the floating-drum and the longer life span of a water jacket plant.

b) **Fixed dome type of biogas plant (Constant Volume):** This type of plant requires only masonry work that's why it's economical in construction. Pressure in gas varies depending on the production and consumption rate. A dome structure is very strong for outside pressure but weaker for inside pressure. A skilled masonry is required for construction of dome as gas exerts pressure from inside out, the dome structure may be failed. The slurry enters from the inlet, and the digested slurry is collected in displacement tank. If the raw material is crop residue than stirring is required. As there is no bifurcation in digester chamber, therefore the gas production is somewhat very low as compared to floating point design. The gas stored in the dome is stored in the dome and displaces liquid in inlets and outlet, sometimes leading gas pressure as high as 100 cm of water. The gas occupies about 10% of the volume of the digester. The complete plant is constructed underground therefore temperature tends to remain constant and is often higher than in winter. Many variations in basic models are developed keeping in view the portability, ease of installation and maintenance, local availability of material and cost [11].

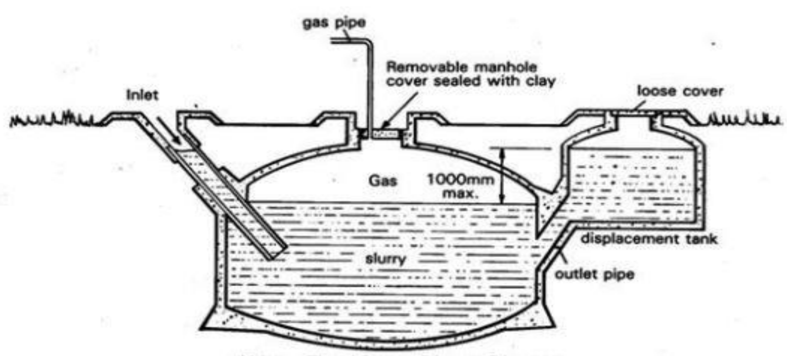


Fig. 5: Fixed dome type of biogas plant [14].

<u>Types of floating drum type biogas plant [12].</u>

- Chinese fixed-dome plant is the archetype of all fixed dome plants. Several million have been constructed in China. The digester consists of a cylinder with round bottom and top.
- Janata model was the first fixed-dome design in India, as a response to the Chinese fixed dome plant. It is not constructed anymore. The mode of construction lead to cracks in the gasholder - very few of these plant had been gas-tight.

- Deenbandhu, the successor of the Janata plant in India, with improved design, was more crack-proof and consumed less building material than the Janata plant. with a hemisphere digester
- CAMARTEC model has a simplified structure of a hemispherical dome shell based on a rigid foundation ring only and a calculated joint of fraction, the so-called weak / strong ring. It was developed in the late 80s in Tanzania.
- AKUT fixed dome plant is an improvement of the above mentioned Nicaragua design. Digester volumes ranges from 8 to 124 m³ with gas storages from 2 to 19,4 m³; the gas production can reach 60 m³/d. The units from 32 m³ onwards are often used for small scale productive use including electricity generation. It has a cylindrical base with a spherical top. The expansion chamber acts as overpressure outlet.
- AKUT Maendaleo (kisuaheli "progress") adds a gas storage balloon to collect access gas from the digestion chamber. This can be used for converted Diesel generators.

1.5 DEVELOPMENT AROUND THE WORLD [7].

United States

With the many benefits of biogas, it is starting to become a popular source of energy and is starting to be used in the United States more. In 2003, the United States consumed 43 TWh (147 trillion BTU) of energy from "landfill gas", about 0.6% of the total U.S. natural gas consumption. Methane biogas derived from cow manure is being tested in the U.S. According to a 2008 study, collected by the Science and Children magazine, methane biogas from cow manure would be sufficient to produce 100 billion kilowatt hours enough to power millions of homes across America. Furthermore, methane biogas has been tested to prove that it can reduce 99 million metric tons of greenhouse gas emissions or about 4% of the greenhouse gases produced by the United States.

In Vermont, for example, biogas generated on dairy farms was included in the CVPS Cow Power program. The program was originally offered by Central Vermont Public Service Corporation as a voluntary tariff and now with a recent merger with Green Mountain Power is now the GMP Cow Power Program. Customers can elect to pay a premium on their electric bill, and that premium is passed directly to the farms in the program. In Sheldon, Vermont, Green

Mountain Dairy has provided renewable energy as part of the Cow Power program. It started when the brothers who own the farm, Bill and Brian Rowell, wanted to address some of the manure management challenges faced by dairy farms, including manure odor, and nutrient availability for the crops they need to grow to feed the animals. They installed an anaerobic digester to process the cow and milking center waste from their 950 cows to produce renewable energy, a bedding to replace sawdust, and a plant-friendly fertilizer. The energy and environmental attributes are sold to the GMP Cow Power program. On average, the system run by the Rowels produces enough electricity to power 300 to 350 other homes. The generator capacity is about 300 kilowatts.

In Hereford, Texas, cow manure is being used to power an ethanol power plant. By switching to methane biogas, the ethanol power plant has saved 1000 barrels of oil a day. Over all, the power plant has reduced transportation costs and will be opening many more jobs for future power plants that will rely on biogas.

In Oakley, Kansas, an ethanol plant considered to be one of the largest biogas facilities in North America is using Integrated Manure Utilization System "IMUS" to produce heat for its boilers by utilizing feedlot manure, municipal organics and ethanol plant waste. At full capacity the plant is expected to replace 90% of the fossil fuel used in the manufacturing process of ethanol and methanol.

In California, the Southern California Gas Company has advocated for mixing biogas into existing natural gas pipelines. However, California state officials have taken the position that biogas is "better used in hard-to-electrify sectors of the economy-- like aviation, heavy industry and long-haul trucking. Similarly cow dung various plants material like the residue after harvesting the crops

Europe

The level of development varies greatly in Europe. While countries such as Germany, Austria and Sweden are fairly advanced in their use of biogas, there is a vast potential for this renewable energy source in the rest of the continent, especially in Eastern Europe. Different legal frameworks, education schemes and the availability of technology are among the prime reasons behind this untapped potential. Another challenge for the further progression of biogas has been negative public perception.

In February 2009, the European Biogas Association (EBA) was founded in Brussels as a non-profit organization to promote the deployment of sustainable biogas production and use in Europe. EBA's strategy defines three priorities: establish biogas as an important part of Europe's energy mix, promote source separation of household waste to increase the gas potential, and support the production of bio-methane as vehicle fuel. In July 2013, it had 60 members from 24 countries across Europe.

UK

As of September 2013, there are about 130 non-sewage biogas plants in the UK. Most are on-farm, and some larger facilities exist off-farm, which are taking food and consumer wastes.

On 5 October 2010, biogas was injected into the UK gas grid for the first time. Sewage from over 30,000 Oxfords hire homes is sent to do cot sewage treatment works, where it is treated in an anaerobic digester to produce biogas, which is then cleaned to provide gas for approximately 200 homes.

In 2015 the Green-Energy company Ecotricity announced their plans to build three grid-injecting digesters.

Italy

As of September 2018, in Italy there are more than 200 biogas plants with a production of about 1.2GW

Germany

Germany is Europe's biggest biogas producer[57] and the market leader in biogas technology. In 2010 there were 5,905 biogas plants operating throughout the country: Lower Saxony, Bavaria, and the eastern federal states are the main regions.[59] Most of these plants are employed as power plants. Usually the biogas plants are directly connected with a CHP which produces electric power by burning the bio methane. The electrical power is then fed into the public power grid.[60] In 2010, the total installed electrical capacity of these power plants was 2,291 MW.[59] The electricity supply was approximately 12.8 TWh, which is 12.6% of the total generated renewable electricity.

Biogas in Germany is primarily extracted by the co-fermentation of energy crops (called 'NawaRo', an abbreviation of nachwachsende Rohstoffe, German for renewable resources) mixed with manure. The main crop used is corn. Organic waste and industrial and agricultural residues such as waste from the food industry are also used for biogas generation.[62] In this respect, biogas production in Germany differs significantly from the UK, where biogas generated from landfill sites is most common.

Biogas production in Germany has developed rapidly over the last 20 years. The main reason is the legally created frameworks. Government support of renewable energy started in 1991 with the Electricity Feed-in Act (StrEG). This law guaranteed the producers of energy from renewable sources the feed into the public power grid, thus the power companies were forced to take all produced energy from independent private producers of green energy. In 2000 the Electricity Feed-in Act was replaced by the Renewable Energy Sources Act (EEG). This law even guaranteed a fixed compensation for the produced electric power over 20 years. The amount of around 8 ¢/kWh gave farmers the opportunity to become energy suppliers and gain a further source of income.

The German agricultural biogas production was given a further push in 2004 by implementing the so-called NawaRo-Bonus. This is a special payment given for the use of renewable resources, that is, energy crops. In 2007 the German government stressed its intention to invest further effort and support in improving the renewable energy supply to provide an answer on growing climate challenges and increasing oil prices by the 'Integrated Climate and Energy Programme'.

This continual trend of renewable energy promotion induces a number of challenges facing the management and organization of renewable energy supply that has also several impacts on the biogas production. The first challenge to be noticed is the high area-consuming of the biogas electric power supply. In 2011 energy crops for biogas production consumed an area of circa 800,000 ha in Germany. This high demand of agricultural areas generates new competitions with the food industries that did not exist hitherto. Moreover, new industries and markets were created in predominately rural regions entailing different new players with an economic, political and civil background. Their influence and acting has to be governed to gain all advantages this new source of energy is offering. Finally biogas will furthermore play an important role in the German renewable energy supply if good governance is focused.

Indian subcontinent

Biogas in India has been traditionally based on dairy manure as feed stock and these "gobar" gas plants have been in operation for a long period of time, especially in rural India. In the last 2–3 decades, research organizations with a focus on rural energy security have enhanced the design of the systems resulting in newer efficient low cost designs such as the Deenabandhu model.

The Deenabandhu Model is a new biogas-production model popular in India. (Deenabandhu means "friend of the helpless.") The unit usually has a capacity of 2 to 3 cubic metres. It is constructed using bricks or by a Ferro mixture. In India, the brick model costs slightly more than the Ferro-cement model; however, India's Ministry of New and Renewable Energy offers some subsidy per model constructed.

Biogas which is mainly methane/natural gas can also be used for generating protein rich cattle, poultry and fish feed in villages economically by cultivating Methylococcus capsulatus bacteria culture with tiny land and water foot print. The carbon dioxide gas produced as by product from these plants can be put to use in cheaper production of algae oil or spiraling from alga culture particularly in tropical countries like India which can displace the prime position of crude oil in near future. Union government of India is implementing many schemes to utilise productively the agro waste or biomass in rural areas to uplift rural economy and job potential. With these plants, the non edible biomass or waste of edible biomass is converted in to high value products without any water pollution or green house gas (GHG) emissions.

LPG (Liquefied Petroleum Gas) is a key source of cooking fuel in urban India and its prices have been increasing along with the global fuel prices. Also the heavy subsidies provided by the successive governments in promoting LPG as a domestic cooking fuel has become a financial burden renewing the focus on biogas as a cooking fuel alternative in urban establishments. This has led to the development of prefabricated digester for modular deployments as compared to RCC and cement structures which take a longer duration to construct. Renewed focus on process technology like the Biourja process model has enhanced the stature of medium and large scale anaerobic digester in India as a potential alternative to LPG as primary cooking fuel.

In India, Nepal, Pakistan and Bangladesh biogas produced from the anaerobic digestion of manure in small-scale digestion facilities is called gobar gas; it is estimated that such facilities exist in over 2 million households in India, 50,000 in Bangladesh and thousands in Pakistan, particularly North Punjab, due to the thriving population of livestock. The digester is an airtight circular pit made of concrete with a pipe connection. The manure is directed to the pit, usually straight from the cattle shed. The pit is filled with a required quantity of wastewater. The gas pipe is connected to the kitchen fireplace through control valves. The combustion of this biogas has very little odor or smoke. Owing to simplicity in implementation and use of cheap raw materials in villages, it is one of the most environmentally sound energy sources for rural needs. One type of these system is the Sintex Digester. Some designs use vermiculture to further enhance the slurry produced by the biogas plant for use as compost.

In Pakistan, the Rural Support Programs Network is running the Pakistan Domestic Biogas Programs which has installed 5,360 biogas plants and has trained in excess of 200 masons on the technology and aims to develop the Biogas Sector in Pakistan.

In Nepal, the government provides subsidies to build biogas plant at home.

China

The Chinese have experimented with the applications of biogas since 1958. Around 1970, China had installed 6,000,000 digesters in an effort to make agriculture more efficient. During the last years the technology has met high growth rates. This seems to be the earliest developments in generating biogas from agricultural waste.

The rural biogas construction in China has shown an increased development trend. The exponential growth of energy supply caused by rapid economic development and severe haze condition in China have led biogas to become the better eco-friendly energy for rural area. In Qing country, Hebei Province, the technology of using crop straw as main material to generate biogas is currently developing.

China had 26.5 million biogas plants, with an output of 10.5 billion cubic meter biogas until 2007. The annual biogas output has increased to 248 billion cubic meter in 2010.[82] The Chinese government had supported and funded rural biogas projects, but only about 60% were operating normally. During the winter, the biogas production in northern regions of China is lower. This is caused by the lack of heat control technology for digesters thus the co-digestion of different feedstock failed to complete in the cold environment.

In developing nations

Domestic biogas plants convert livestock manure and night soil into biogas and slurry, the fermented manure. This technology is feasible for small-holders with livestock producing 50 kg manure per day, an equivalent of about 6 pigs or 3 cows. This manure has to be collectable to mix it with water and feed it into the plant. Toilets can be connected. Another precondition is the temperature that affects the fermentation process. With an optimum at 36 C° the technology especially applies for those living in a (sub) tropical climate. This makes the technology for small holders in developing countries often suitable.

Depending on size and location, a typical brick made fixed dome biogas plant can be installed at the yard of a rural household with the investment between US$300 to $500 in Asian countries and up to $1400 in the African context. A high quality biogas plant needs minimum maintenance costs and can produce gas for at least 15–20 years without major problems and re-investments. For the user, biogas provides clean cooking energy, reduces indoor air pollution, and reduces the time needed for traditional biomass collection, especially for women and children. The slurry is a clean organic fertilizer that potentially increases agricultural productivity.

Domestic biogas technology is a proven and established technology in many parts of the world, especially Asia. Several countries in this region have embarked on large-scale programs on domestic biogas, such as China and India.

The Netherlands Development Organisation, SNV, supports national programs on domestic biogas that aim to establish commercial-viable domestic biogas sectors in which local companies market, install and service biogas plants for households. In Asia, SNV is working in Nepal, Vietnam, Bangladesh, Bhutan, Cambodia, Lao PDR, Pakistan and Indonesia, and in Africa; Rwanda, Senegal, Burkina Faso, Ethiopia, Tanzania, Uganda, Kenya, Benin and Cameroon.

In South Africa a prebuilt Biogas system is manufactured and sold. One key feature is that installation requires less skill and is quicker to install as the digester tank is premade plastic.

1.6 ADVANTAGES, BENEFITES AND APPLICATION OF BIOGAS.

1.6.1 Advantages of Biogas [15].

a) **Biogas is Eco-Friendly:** Biogas is a renewable, as well as a clean, source of energy. Gas generated through biodigestion is non-polluting; it actually reduces greenhouse emissions (i.e. reduces the greenhouse effect). No combustion takes place in the process, meaning there is zero emission of greenhouse gasses to the atmosphere; therefore, using gas from waste as a form of energy is actually a great way to combat global warming.

Unsurprisingly, concern for the environment is a major reason why the use of biogas has become more widespread. Biogas plants significantly curb the greenhouse effect: the plants lower methane emissions by capturing this harmful gas and using it as fuel. Biogas generation helps cut reliance on the use of fossil fuels, such as oil and coal.

Another biogas advantage is that, unlike other types of renewable energies, the process is natural, not requiring energy for the generation process. In addition, the raw materials used in the production of biogas are renewable, as trees and crops will continue to grow. Manure, food scraps, and crop residue are raw materials that will always be available, which makes it a highly sustainable option.

b) **Biogas Generation Reduces Soil and Water Pollution:** Overflowing landfills don't only spread foul smells- they also allow toxic liquids to drain into underground water sources. Consequently, yet another advantage of biogas is that biogas generation may improve water quality. Moreover, anaerobic digestion deactivates pathogens and parasites; thus, it's also quite effective in reducing the incidence of waterborne diseases. Similarly, waste collection, and management, significantly improves in areas with biogas plants. This, in turn, leads to improvements in the environment, sanitation, and hygiene.

c) **Biogas Generation Produces Organic Fertilizer:** The by-product of the biogas generation process is enriched organic (digester), which is a perfect supplement to, or substitute for, chemical fertilizers. The fertilizer discharge from the digester can accelerate plant growth and resilience to diseases, whereas commercial fertilizers contain chemicals that have toxic effects and can cause food poisoning, among other things.

d) **It's a Simple and Low-Cost Technology That Encourages a Circular Economy:** The technology used to produce biogas is quite cheap. It is easy to set up and needs little investment when on a small scale. Small biodigesters can be used right at home, utilizing kitchen waste and animal manure. A household system pays for itself after a while, and the materials used for generation are absolutely free. The gas manifested can be used directly for cooking and generation of electricity. This is what allows the cost of biogas production to be relatively low.

Farms can make use of biogas plants and waste products produced by their livestock every day. The waste products of one cow can provide enough energy to power a lightbulb for an entire day.

In large plants, biogas can also be compressed to achieve the quality of natural gas, and utilized to power automobiles. Building such plants requires relatively low capital investment, and creates green jobs. For instance, in India, 10 million jobs were created, mostly in rural areas, in plants and in organic waste collection.

e) **Healthy Cooking Alternative for Developing Areas:** Biogas generators save women and children from the daunting task of firewood collection. As a result, more time is left over for cooking and clean. More importantly, cooking on a gas stove, instead of over an open fire, prevents the family from being exposed to smoke in the kitchen. This helps prevent deadly respiratory diseases. Sadly, 4.3 million people a year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels for cooking.

1.6.2 Benefits of Biogas [15].

a) **Diversion of Organics from Landfills:** Organic materials can be separated from the municipal solid waste (MSW) stream and processed in an anaerobic digester. These materials include: Food scraps from residential properties; Food scraps from businesses (e.g., restaurants); Commercial food processing waste; Fats, oils and greases; and Yard waste. Keeping organic materials out of landfills is beneficial for the environment. If these materials are allowed to decay in landfills, methane and carbon dioxide can be released into the air and contribute to climate change. The loss of valuable nutrients from our ecosystem is another downside to land filling organic materials. When these materials are anaerobically digested, the resulting nutrients found in digestate can be used to feed and nourish the soil.

b) **Renewable Energy Generation:** When organic materials are anaerobically digested, biogas is created. Biogas is a renewable source of energy.

c) **Soil Health Benefits:** It is important to maintain soils that are healthy and productive to grow food to feed our local, national and world populations. Anaerobic digestion produces digestate, nutrient-rich slurry. Digestate can be applied to agricultural land as a fertilizer and/or soil amendment to improve soil health. Digestate that is applied to land is subject to both state and federal regulations.

d) **Methane Emissions Reduction:** Methane is created when organic materials decompose in oxygen-free environments like landfills and manure lagoons. Anaerobic digestion systems capture methane and allow us to use that methane in a beneficial way. Capturing methane is important because methane is a potent greenhouse gas that contributes to climate change if allowed to escape to the atmosphere.

1.6.3 Application of Biogas [7].

a) **Biogas in transport:** If concentrated and compressed, it can be used in vehicle transportation. Compressed biogas is becoming widely used in Sweden, Switzerland, and Germany. A biogas-powered train, named Biogaståget Amanda (The Biogas Train Amanda), has been in service in Sweden since 2005. Biogas powers automobiles. In 1974, a British documentary film titled *Sweet as a Nut* detailed the biogas production process from pig manure and showed how it fueled a custom-adapted combustion engine. In 2007, an estimated 12,000 vehicles were being fueled with upgraded biogas worldwide, mostly in Europe.

Biogas is part of the wet gas and condensing gas (or air) category that includes mist or fog in the gas stream. The mist or fog is predominately water vapor that condenses on the sides of pipes or stacks throughout the gas flow. Biogas environments include wastewater digesters, landfills, and animal feeding operations (covered livestock lagoons).

Ultrasonic flow meters are one of the few devices capable of measuring in a biogas atmosphere. Most of thermal flow meters are unable to provide reliable data because the moisture causes steady high flow readings and continuous flow spiking, although there are single-point insertion thermal mass flow meters capable of accurately monitoring biogas flows with minimal pressure drop. They can handle moisture variations that occur in the flow stream because of daily and seasonal temperature fluctuations, and account for the moisture in the flow stream to produce a dry gas value.

b) **Biogas generated heat/electricity:** Biogas can be used in different types of internal combustion engines, such as the GE Jenbacher or Caterpillar gas engines. Other internal combustion engines such as gas turbines are suitable for the conversion of biogas into both electricity and heat. The digestate is the remaining inorganic matter that was not transformed into biogas. It can be used as an agricultural fertilizer.

Biogas can be used as the fuel in the system of producing biogas from agricultural wastes and co-generating heat and electricity in a combined heat and power (CHP) plant. Unlike the other green energy such as wind and solar, the biogas can be quickly accessed on demand. The global warming potential can also be greatly reduced when using biogas as the fuel instead of fossil fuel.

However, the acidification and eutrophication potentials produced by biogas are 25 and 12 times higher respectively than fossil fuel alternatives. This impact can be reduced by using correct combination of feedstock's, covered storage for digesters and improved techniques for retrieving escaped material. Overall, the results still suggest that using biogas can lead to significant reduction in most impacts compared to fossil fuel alternative. The balance between environmental damage and green house gas emission should still be considered while implicating the system.

CHAPTER 2

LITERATURE SURVEY

Several studies have been carried out by many researchers in order to optimize biogas yield in anaerobic digester, improving contact between bacteria and substrate using stirring[16], and controlling ammonia inhibition [17,18].

P.M. Ndegwa , D.W. Hamilton, J.A. Lalman, H.J. Cumba [19]. Have carried out research which had the results that suggest within the parameter range under consideration, temperature did not affect the biogas yield significantly; however, higher cycle-frequency had a negative effect. The biogas quality (% CH_4) was not significantly affected by temperature or by the cycle frequency. The operating principle of the anaerobic sequencing batch reactor (ASBR) follows four phases: feed, react, settle, and decant in a cyclic mode. To improve the biogas production in an ASBR, one long react-phase was preferable compared to three shorter react-phases. Treatment of dilute manure slurries in an ASBR at 20^{o}C was more effective than at 35^{o}C; similarly more bio-stable effluents were obtained at low cycle-frequency. The treatment of dilute swine slurries in an ASBR at the lower temperature (20^{o}C) and lower cycle-frequency is, therefore, recommended for the bio-stabilization of dilute swine waste waters. The results also indicate that significantly higher Volatile fatty acid (VFA) degradation occurred at 20^{o}C than at 35^{o}C, suggesting that the treatment of dilute swine slurries in ASBRs for odor control might be more favorable at the lower than at the higher temperatures examined in this study. Volatile fatty acid reduction at the two reactor temperatures and cycle frequencies, from a high of 639 ± 75 mg/L to a low of 92 ± 23 mg/L, greatly reduced the odor and the odor-generation potential in post-treatment storage. The nutrients (both N and P) in the waste influent were conserved in the effluents.

D. R. Vartak, C. R. Engler, M. J. McFarland & S. C. Ricke [20]. Have observed from their research that retention of microorganisms in anaerobic digesters by providing an attachment medium can potentially increase their productivity at lower operating temperatures. The objective of this work was to investigate the effectiveness of attached-film bioreactors for psychrophilic anaerobic digestion of dairy manure. Eight digesters were maintained in an environmental chamber, with the temperature varied between 37°C and 10°C. Two digesters were packed with limestone gravel, two with pieces cut from non-woven polyester matting; two with a combination of limestone gravel and polyester pieces, and two had no packing. Digester operation was initiated at a temperature of 37ºC. After the digesters reached stable operation at the initial temperature, the temperature was lowered slowly to 10°C. The temperature was held at 10°C for 5 weeks after stabilizing. The polyester medium with its high porosity and surface to volume ratio had the best overall performance for methane productivity at both 37ºC and 10°C. The biogas production (ml/d) and methane production (ml/d) were significantly higher for the polyester medium when compared to the limestone and combination media. At 10°C, the polyester medium reactors performed significantly better than all others for biogas (ml/d) and methane (ml/d) production. The polyester medium also yielded the maximum reductions in volatile solids (VS) and chemical oxygen demand (COD) at 37°C.

Budiyono et al [21] carried out investigations on the kinetic of biogas production from cattle manure in batch mode digester. In their studies cattle manure as substrate is inoculated by rumen fluid to the anaerobic bio digester. They have found that the liquid rumen seeded to bio digester has significant effect to cumulative biogas production and biogas production rate. Rumen fluid inoculums caused biogas production rate and efficiency increase two to three times in compare to manure substrate without rumen fluid.

Vytautas Kalpokas [22] carried out investigations on experimental investigation of biogas production using pig manure and slaughter house wastes were mixed at 95% : 5%, 90% : 10% and 85% : 15% in volume. The mixtures of pig manure and slaughterhouse wastes at ratio 9:1 and 17:3 postponed the digestion process in bioreactor. The concentration of methane was reached 60% after 3 weeks from the beginning the experiment.

A. Orfanoudaki1, G. Makridakis, A. Maragkaki , M. S. Fountoulakis , N. G. Kallithrakas-Kontos , T. Manios [23]. Have carried out research on proper choosing of co-substrate compositions leads to system balance and increased methane generation. Spent coffee grounds (SCG) are an unexploited material produced in large quantities which seems suitable for anaerobic digestion. During this study SCG were tested for biogas production in both batch and continuous reactors. Specifically, the biochemical methane potential of SCG was calculated in serum bottle test reactors at two different inoculums to substrate ratios (ISRs). In addition, co-digestion of SCG with liquid pig manure as co-substrate was monitored in a pilot scale continuously stirred tank reactor. Maximum methane production was similar at both ISRs, indicating no inhibition effects. Moreover, results from continuous experiments show that the methane production rate increased significantly after the addition of SCG to the digester. The reactor treating the liquid pig manure produced approximately 0.12 $L_{biogas}/L_{reactor}$/d before the addition of SCG and 1.4 $L_{biogas}/L_{reactor}$/d after the addition. The average removal of dissolved chemical oxygen demand increased from 20 to 40% after the addition of SCG. The concept of co-digestion could be a promising perspective for anaerobic digestion units as it increases methane production significantly.

M. Shamsul Haque and M. Naimul Haque [24]. A research was carried out by taking cattle urine also as one of constituent with cow dung and water has observed that gas production has been increased up to 30 % at a proportion of 50:35:15 (cow dung : urine : water) and 10 % at a proportion of 50:5:45. They also observed that gas production increases with the increase of urine and reaches a maximum and then decreases even with the increase of urine in the substrate. This is, may be due to the excess of Nitrogen in the slurry.

Navodita Bhatnagar, David Ryan, Richard Murphy, Anne-Marie Enright [25]. A research was done Anaerobic Digestion which has its own challenges, especially, ammonia inhibition and volatile fatty acid (VFA) accumulation. Co-digestion and enzyme supplementation can help overcome these challenges by improving substrate bioavailability and by maintaining nutrient balance respectively. Current study uses grass silage (GS) as a co-substrate for AD of CL along with supplementation of fungal enzyme cocktail.

- Specific Biogas yield (SBY): Highest for 1:3 co-digested of CL and GS (1056.8ml/gVS), an increase of 28% compared to single substrates.

- Specific Methane Yield (SMY): 1% enzyme yielded the highest SMY of 591.72mlCH_4/g VS (25% increase from untreated control).

Dahunsi [26] reported that mechanical pretreatment applied to six different lignocelluloses caused breakdown of structural material and increased the methane yield up to 22%. However, it is observed that excessive size reduction of lignocellulosic biomass can lead to a lower efficiency of methane production. Process efficiency in terms of cost-energy, operational aspects such as the right particle size, processing time of mechanical pretreatment, and the mechanical speed for size reduction must be standardized. It can be observed from literature that there is no universal particle size suitable for biomethanation process and it varies according to the type of the substrate and the process used for biomethanation.

L. R. Miramontes-Martínez, R. Gomez-Gonzalez, J. E. Botello-Álvarez, C. Escamilla-Alvarado, A. Albalate-Ramírez and P. Rivas-García [27] have carried out research on anaerobic digestion of vegetable waste (VW) which often shows the accumulation of fatty acids and low buffering capacity that promotes instability and low methane productivity. This work evaluated the anaerobic co-digestion of VW with cow manure (CM) as a strategy to improve the process stability. As a reaction system, a 4 L semi-continuous stirred tank reactor with an HRT of 20 days and fed with a substrate formulation of 40 g of VS was used in two periods: 34 days of VW mono-digestion and 26 days of VW:CM co-digestion. The mono and co-digestion processes were numerically evaluated through three analysis tools: a proposed co-digestion model embedded in the Anaerobic Digestion structure, statistical process control theory, and modeling the pH dynamics as the response of a first-order linear system to an impulse manipulation. The mono-digestion process showed yields of 0.381 lt CH_4/L digester/d, which increased by 14% during co-digestion. The results indicated that in VW: CM co-digestion the pH had a slower dynamical response to the daily pulse feed, keeping the pH within the statistical stability range.

The early warning indicator IA/BA (ratio between intermediate and bicarbonate alkalinity) also stayed away from the failure threshold. It was shown that the addition of CM to a mono-digestion of VW increases the buffer capacity of the system and the production of CH_4, promoting a stable and efficient process.

Mirzaman Zamanzadeh, Live Heldal Hagen, Kine Svensson, Roar Linjordet & Svein Jarle Horn [28]**.** In this work, performance and microbial structure of a digestion (food waste-only) and a co-digestion process (mixture of cow manure and food waste) were studied at mesophilic (37 °C) and thermophilic (55 °C) temperatures. The highest methane yield (480 ml/g VS) was observed in the mesophilic digester (MDi) fed with food waste alone. The mesophilic co-digestion of food waste and manure (McoDi) yielded 26% more methane than the sum of individual digestions of manure and food waste. The degradation of organic material in all the digesters was measured in terms of TCOD removal. Regardless of the operational temperature, the removal efficiencies were higher for the digestion systems (MDi: 73.0% and TDi: 66.4%) than the co-digesters (McoDi: 61.4% and TcoDi: 56.7%). This was expected due to a general high degradability of food waste. MDi had the highest methane yield of all four digesters with which was 11.5%, 7.0% and 31.6% higher than the McoDi, TDi and TcoDi, respectively. These results are in agreement with earlier studies reported elsewhere. Additionally, lower methane production in the thermophilic reactors may be related to the presence of higher free ammonia concentrations that was, on average, 198 mg/L for TDi and 431 mg/L in TcoDi, potentially causing inhibition of the Methanogenesis process.

It has been observed that co-digestion of food waste and manure may enhance biogas production, and lead to more stable digestion processes. We also observed higher methane production when we compared the methane yield of McoDi fed with the mixture of food waste and manure with that of manure-only fed mesophilic (37 °C) digester. However, our results showed that the observed methane yield of McoDi was 430 mlCH_4/g VS feed, meaning that the co-digestion of food waste and manure (McoDi) resulted in 26% higher methane production than the sum of digestions of individual substrates.

Malgorzata Lochyn ska, Jakub Frankowski [29]. Have studies which showed that the examined substrates, both silkworm breeding waste and caterpillar excreta; generate a biogas yield comparable to other substrates of agricultural origin, such as cattle, pig and chicken manures. Fermentation of silkworm excreta under mesophilic conditions produces 167.32 m^3/Mg TS of methane and 331.97 m^3/Mg TS of biogas, while fermentation of silkworm breeding waste yields 256.59 m^3/Mg TS of methane and 489.24 m^3/Mg TS of biogas. Moreover, the chemical composition of these raw materials was analyzed.

CHAPTER 3

METHODOLOGY

3.1. ANALYSIS OF BIOMASS SAMPLES

Fig.6: Ultimate analysis equipment setup

Ultimate analysis is basically a breaking of the fuel into its elemental components through an analysis of the products that remain after the complete combustion of small fuel sample. Ultimate analysis gives the elemental composition of a fuel. Its determination is relatively difficult and expensive compared to proximate analysis.

The following American Society for Testing and Materials (ASTM) standards are available for determination of the ultimate analysis of biomass components:

Table 2: Standard Methods for Ultimate Analysis of Biomass

Biomass constituent	Standard methods
Carbon	ASTM E 777 for RDF(refuse-derived fuels)
Hydrogen	ASTM E 777 for RDF
Nitrogen	ASTM E 778 for RDF
Moisture	ASTM E 871 for wood, E 949 for RDF, and D 3173 for coal
Ash	ASTM D 1102 for wood, E 1755 for biomass, and D 3174 for coal

3.2 BIOGAS PRODUCTION

3.2.1 Prepartion of bio digester and collecting tube

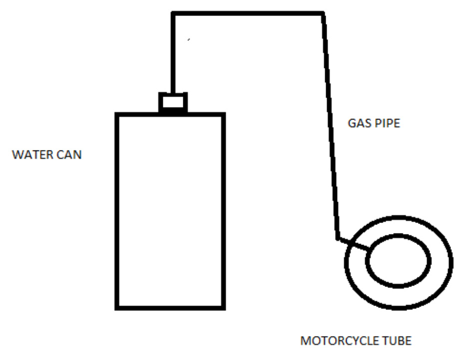


Fig. 7: bio digestor

The bio digester(water can) is cleaned at inner surface to avoid contamination and is dryed for some time and biogas collector(motorcycle tube) is checked for leakage, sealed if any to avoid loss of generated biogas.

3.2.1.1 Dimesion:

Water Can Diameter	-	25 Cm
Water Can Height	-	40 Cm
Tube Effective Radius(r)	-	3.6 Cm
Length of Motorcycle Tube(L)	-	100 Cm

3.2.1.2 Calculation:

Volume of Motorcycle Tube = $\Pi r^2 L = \pi*(3.6^2)*100$

$= 4071.50\ cm^3$

The design and the calculation of the bio digester is done in the prepartion stage to know the quantity of the biomass slurry that can be filled.

The volume of the collection tube is calculated the know the max storage capacity of the tube.

3.2.2 Preparation of Biomass slurry

Fig. 8: Mixing of different biomass.

The slurry is a mixture of different required biomass composition this should be properly mixed first before filling in to bio digester and composition is noted down for naming, this is one which influence development required bacteria for proper production sequence to occur and generated biogas to be purified to increase the methane percentage by in-situ gas purification techniques and by addition of different chemicals into anaerobic digester.

3.2.3 Filling of slurry into digestion chamber

The prepared biomass slurry of different composition is poured into different digester avoiding waste and the digesters are named on its composition for identification.

3.2.4 Fitting pipe connection between tube and bio digester

Fig. 9: Connecting digester to tube

The pipe connections are made between the bio digester & collection tube and joints are made leak proof by properly applying the sealing tape named Bi-axially Oriented Polypropylene (BOPP) due to its sealing capacity and resistant to abrasion, chemically reacting agents, burst and moisture.

Figs. 10: Setup of bio-digester and collection tube

3.3 BIOGAS ANALYSIS

3.3.1 Analysis to know composition and quantity of biogas

Fig. 11: Biogas analyzer

The collection tube is connected to inlet of biogas analyzer, let them for few minutes and reading required is noted down. The analysis is done in controlled environment in to get accurate results.

3.3.2 To know the calorific value of Biogas

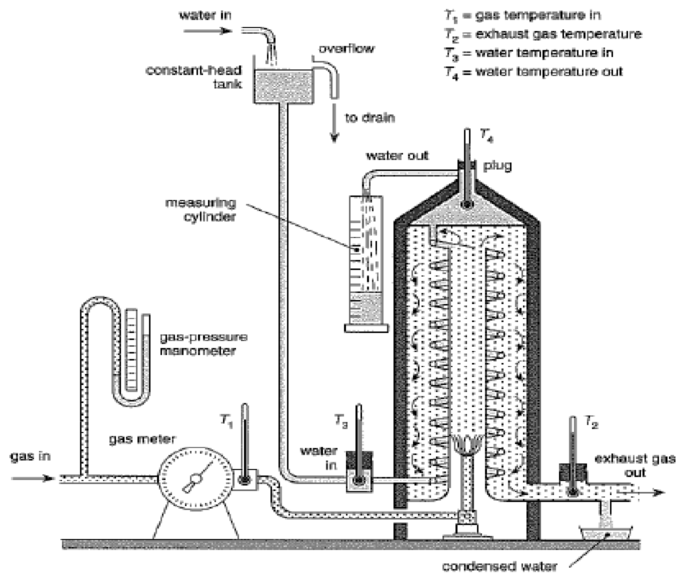


Fig. 12: Junker's calorimeter

Calorific value is the energy contained in a fuel or food, determined by measuring the heat produced by the complete combustion of a specified quantity of it. This is now usually expressed in joules per kilogram and kcal.

The Junker's gas calorimeter is a device used to measure the calorific value of the gaseous fuels. The device is essentially a Bunsen burner with a cooling jacket. The jacket is cylindrical in shape with water in it. The burner is inside the cylinder. The calorimeter allows the user to measure the temperature of water flowing in and flowing out. Once steady state is reached, the water flowing through is collected for a specified period of time. Measuring the mass of the water and the temperature rise in the water, the operator can calculate the number of joules which went into the water to heat it. There is a flow meter on the fuel gas, so the operator can also calculate the volume of gas that was burned in the same time period. The amount of energy, in J, available per liter of gas can then be calculated. A Junkers calorimeter is a flow calorimeter, with heat transfer happening continuously, as opposed to a batch calorimeter.

The device consists of a cylindrical shell and two paths for water are there which have copper coil arranged in it. One path is the inlet and the other is outlet. Water passes through the copper coils. There is pressure regulator in the path of water flow which is further connected with gas flow meter. Gas flow meter is used to measure the flow rate of gas. Temperature sensors are used in the device to measure the inlet and outlet water temperature and also for the flue gases.

The Junker's gas calorimeter works on the principal of burning of gas whose volume is known. The temperature of water and gas is measured along with flow rate of gas to measure the calorific value. The formula is:

1. Calorific value of fuel = $Q_{rw}*0.239$ Kcal
2. Heat received by water(Q_{rw}) = $M_w*C_P*\Delta T$ KJ

Where; V_{gas}: Volume of gas burnt

M_w: Mass of water circulated

C_P: Specific heat of water

ΔT: Rise in water temperature of water in calorimeter

CHAPTER 4

RESULT AND DISCUSSION

4.1 Biomass samples analyzed

The ultimate analysis done on the required biomass samples to know its composition and its contribution to methane content, calorific value of the biogas generated.

Few of the biomass samples send to analysis is:

1. Silkworm larva litter
2. Kitchen waste
3. Cattle urine
4. Cow dung
5. Cashew nut apple

1. <u>Silkworm larva litter:</u> Silk worm litter is a waste from rearing trays (Fig 10). The sericulture waste which includes larval excreta, leaf litter, dead larvae, moth and cocoons contain organic matter.

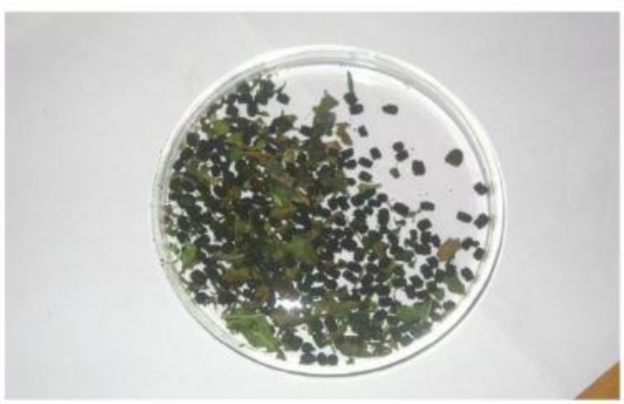


Fig. 13: Freshly collected silkworm larva litter

Table 3: Chemical composition of silkworm larva litter

Compound	Weight fraction (%)
Ash	11

Nitrogen	3.75
Carbon	49.31
Cellulose($C_6H_{10}O_5$)	20.1
Lignin($C_{31}H_{34}O_{11}$)	7.16
Moisture content	8.68

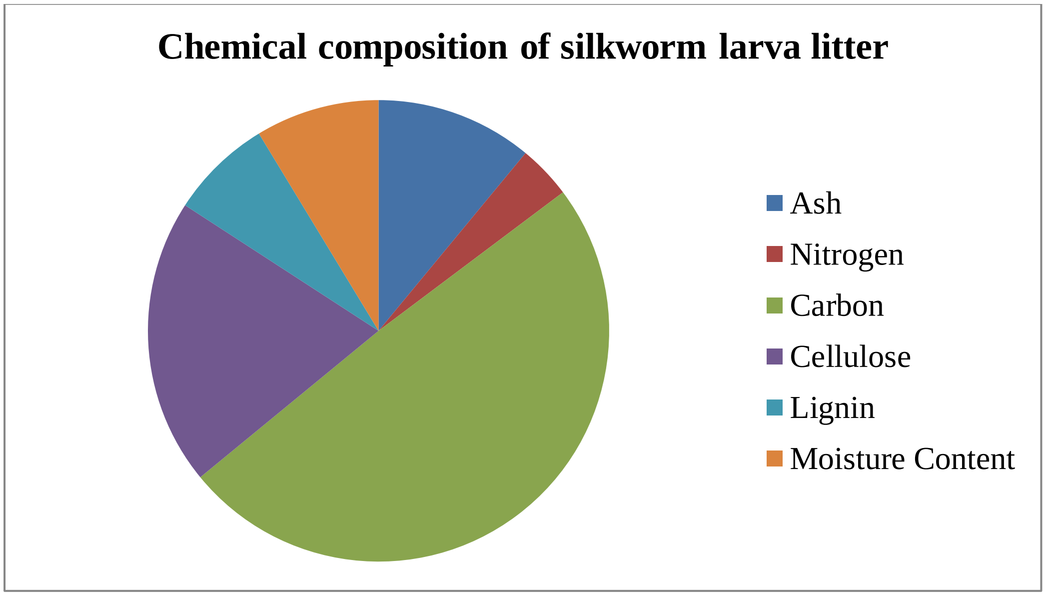


Fig. 14: Chart represents composition of silkworm larva litter

2. Kitchen waste: Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why efficiency of methane production can be increased by several orders of magnitude. It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences. It not only leads to polluting surface and groundwater through leach ate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odor and methane which is a major greenhouse gas contributing to global warming.

Table 4: Chemical composition of Kitten waste

Compound	Weight fraction (in grams)
Ash	11.32
Moisture contents	79.12
Hemi-cellulose	12.77
Protein	7.98
Lignin	6.31
Fat	12.18
Cellulose	18.31
Total solids	16.48
Total volatile solids	77.35
Total organic carbon	56.13
Kjeldahl nitrogen	1.11

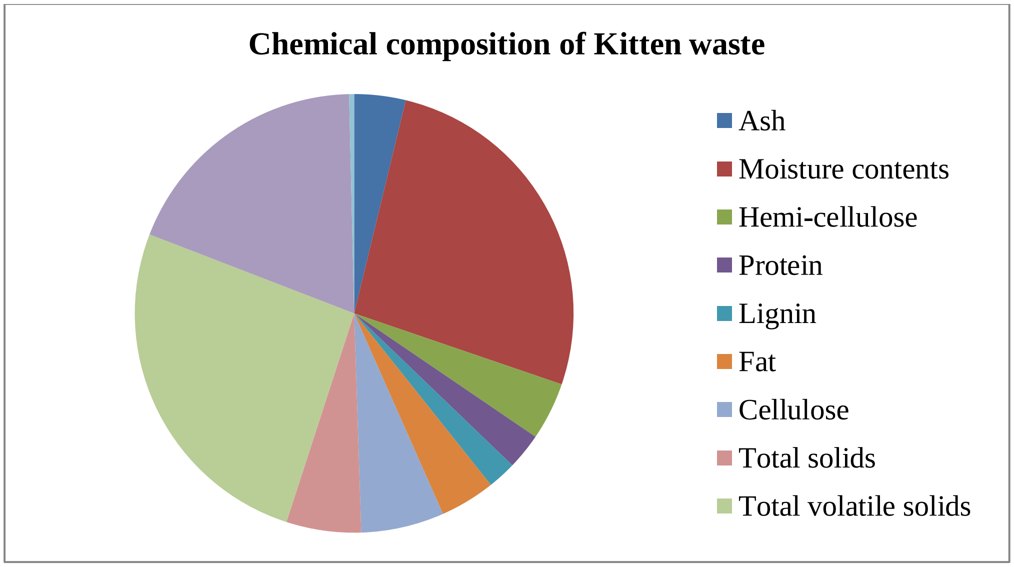


Fig. 15: Chart represents composition of Cow dung

3. Cattle urine: Cow urine is a liquid by-product of metabolism in cows. Cow urine has urea presence which makes the digestion faster.

Table 5: Chemical composition of Cattle urine

Compound	Weight fraction (%)
Water	85
Urea(CH_4N_2O)	12.63
Minerals	0.54
Salts	0.95
Hormones	0.75
Enzymes	0.26

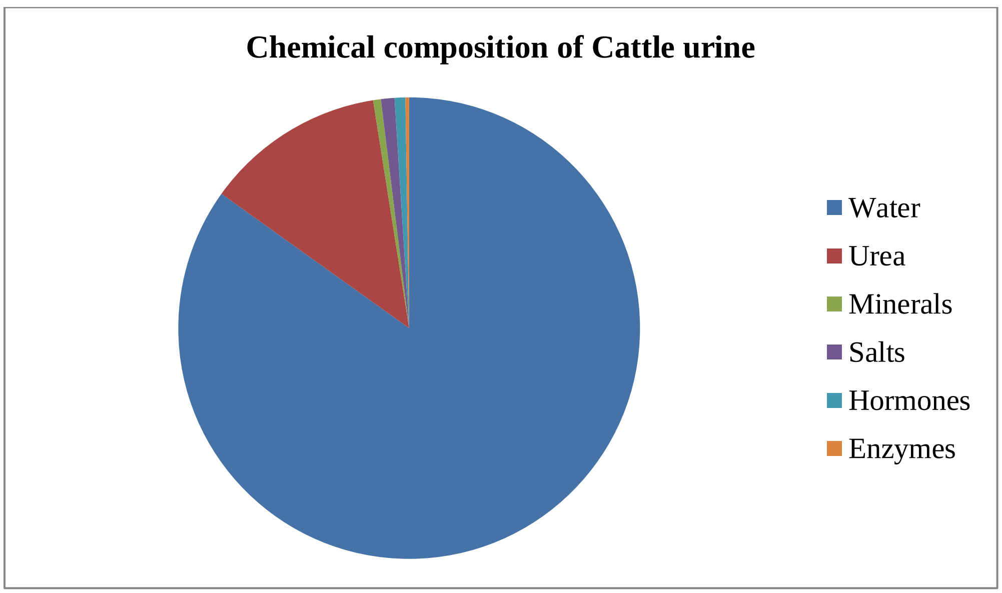


Fig. 16: Chart represents composition of Cattle Urine

4. Cow dung: Cow dung, also known as cow pats, cow pies or cow manure, is the waste product of bovine animal species. These species include domestic cattle ("cows"), bison ("buffalo"), yak, and water buffalo. Cow dung is the undigested residue of plant matter which has passed through the animal's gut. The resultant fecal matter is rich in minerals. Color ranges from greenish to blackish, often darkening soon after exposure to air.

Table 6: Chemical composition of Cow dung

Compound	Weight fraction (in grams)
Moisture contents	77.31
Total solids	22.13
Volatile solids	14.31
Volatile solids (from TS)	79.21
Ash	3.88
Ash (from TS)	28.37
Total organic carbon	48.29
Total nitrogen	2.89

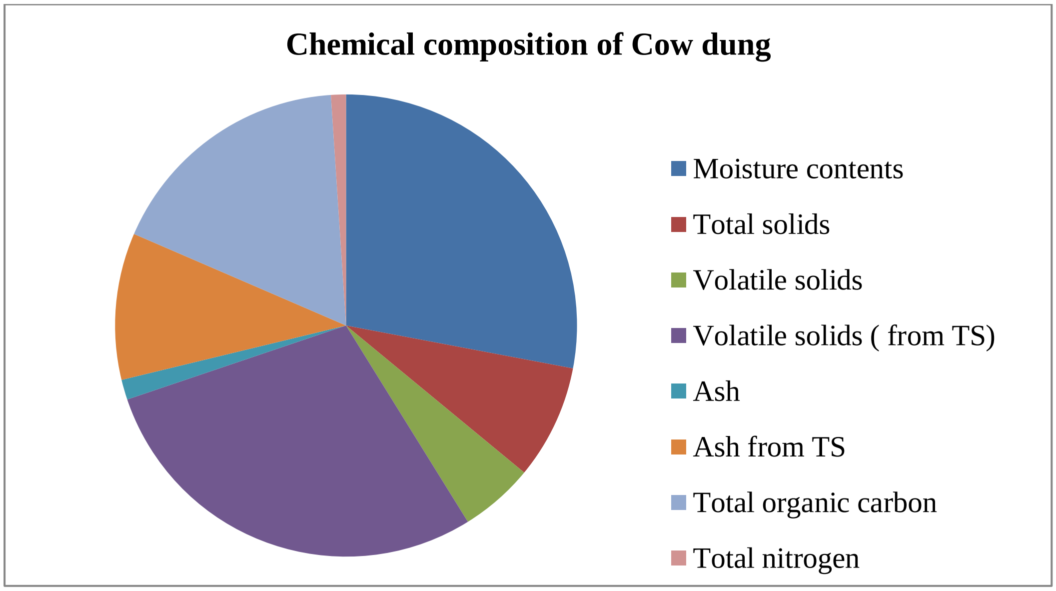


Fig. 17: Chart represents composition of Cow dung

5. <u>Cashew nut apple:</u> Cashew belonging to the family Anacardiaceae is a major commercial horticultural crop of India. It is primarily cultivated for its nut, and widely grown in tropical areas. However, may be due to the high value of the nut, another important produce from cashew i.e. cashew apple, has been neglected all along without any utilization. Cashew apple is very tasty and is highly nutritious. It is comparable with many other tropical fruits in its nutritive value and contains more vitamin C and riboflavin.

Table 7: Chemical composition of Cashew nut apple

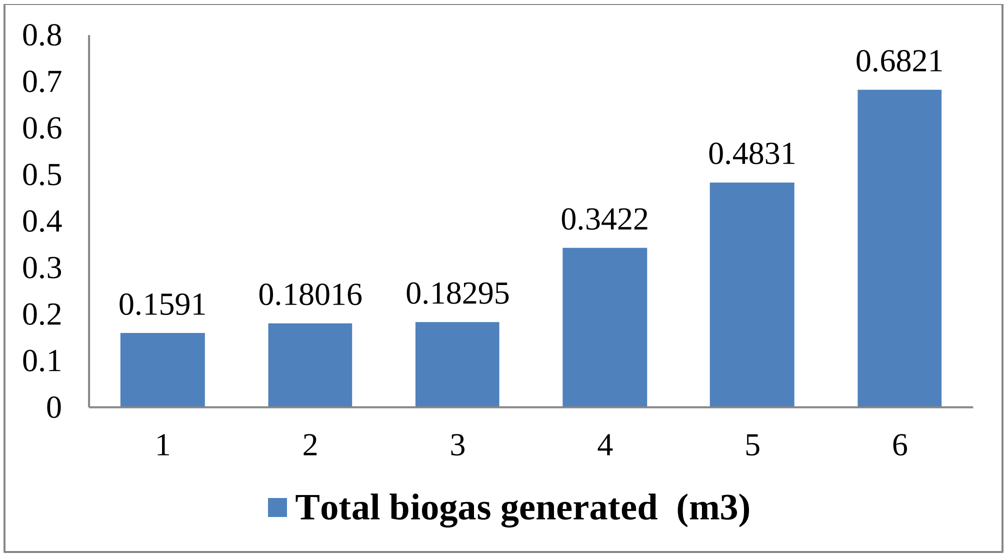
Compound	Weight fraction (in grams)	
	Sample-A	Sample-B
Tannic Acid($C_{76}H_{52}O_{46}$)	1.45	2.5
Sucrose($C_{12}H_{22}O_{11}$)	0.48	1.55
Malic Acid($C_4H_6O_5$)	3.84	5.76
Glucose($C_6H_{12}O_6$)	46.88	45.63
Fructose($C_6H_{12}O_6$)	46.72	44
Ascorbic Acid($C_6H_8O_6$)	0.63	0.56

4.2 Analysis of biogas

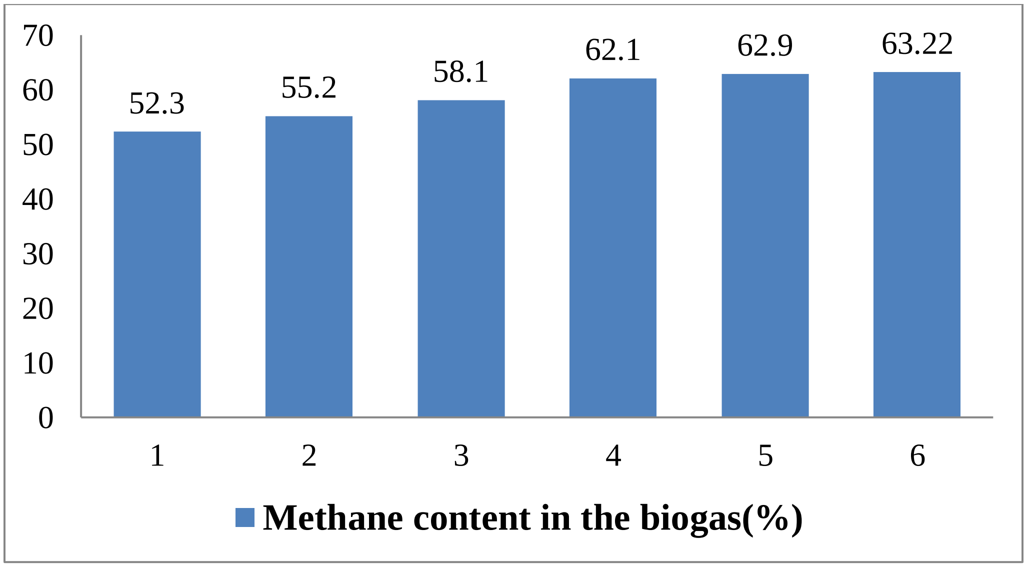
In these observations, analysis has been done under batch system. It has been observed that the production of biogas is dependent upon the temperature, solar intensity and composition of bio mass slurry. Tables 8,9,10 give the comparison of methane percentage, calorific value and volume of biogas generated for various composition of biomass slurry. In these analyses we have 400 kg slurry with different ratio of cow dung, silkworm larval litter and water and cattle urine. The sledge is an aerobically digested and contains anaerobic bacteria which are responsible for biogas production.

Table 8: Comparison among Various Ratio of silkworm larval litter in fiber composite plastic made Biogas Plant.

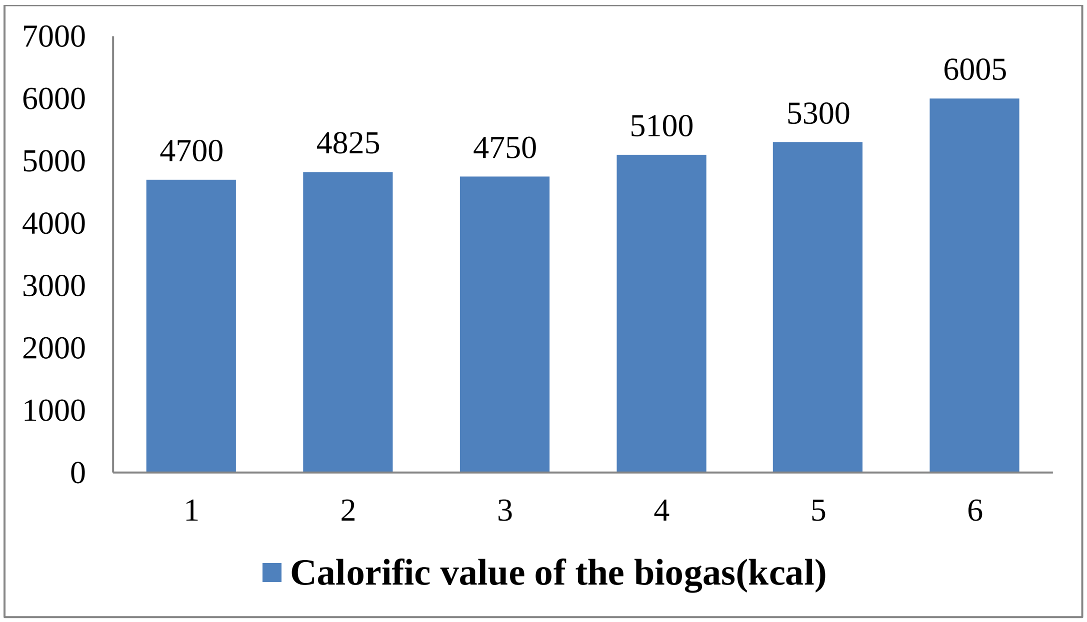
Sl no.	Total mass of slurry in the digester(kg)	Percentage of different biomass composition	Total biogas generated (m^3)	Methane gas% in the biogas	Calorific value of the biogas(kcal)
1	20	60% cow dung+40% water	0.1591	52.3	4700
2	20	50% cow dung+ 30% water + 10% cattle urine + 10% silk worm larva litter	0.18016	55.2	4825
3	20	40% cow dung+ 30% water + 10% cattle urine + 20% silk worm larva litter	0.18295	58.1	4750
4	20	30% cow dung + 30% water + 10% cattle urine + 30% silk worm larva litter	0.3422	62.1	5100
5	20	20% cow dung + 30% water + 10% cattle urine + 40% silk worm larva litter	0.4831	62.9	5300
6	20	10% cow dung + 30% water + 10% cattle urine + 50% silk worm larva litter	0.6821	63.22	6005



As we observed that the bio gas production is increased with increasing the silk warm larval litter as an additive, since silkworm larva litter has 20.1% of Cellulose ($C_6H_{10}O_5$) and 7.16% of Lignin ($C_{31}H_{34}O_{11}$) this has more amounts of oxygen atoms which make digestion faster and high generation rate of Biogas. In our 6th trial majority cow dung is being replaced by the silk warm larval litter here we observe that bio gas produced is about 0.6821 m^3 which is found to be the highest of all above trials, Hence we can say that the silk warm larval litter is affecting on increasing the bio gas production.



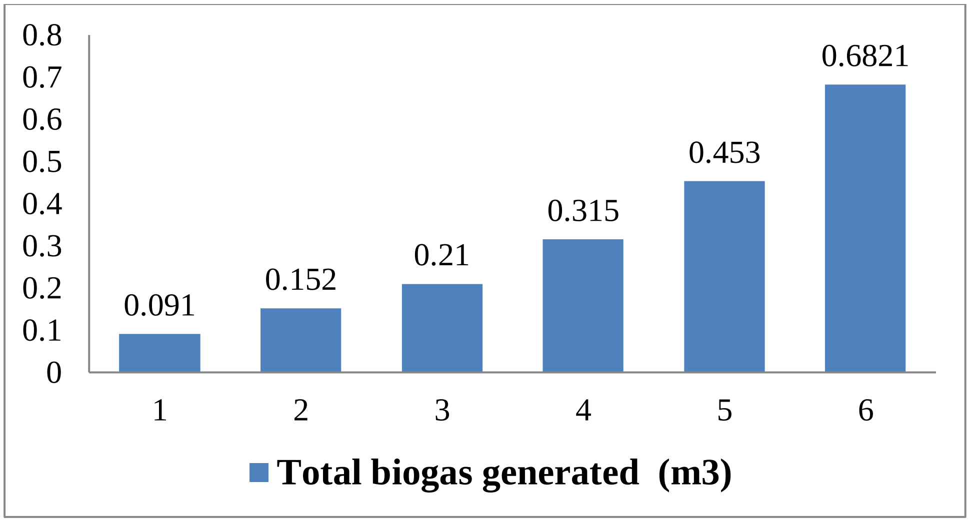
We know that silkworm larva litter has Cellulose ($C_6H_{10}O_5$) and Lignin ($C_{31}H_{34}O_{11}$) in 20.1% and 7.16% respectively this contribute more for methane content in biogas due to high content of carbon and hydrogen atoms. From the graph we can observe that trial 6 has highest percent of methane content that is 63.22% of total gas generated this can be concluded as methane content has increased with increase in silkworm larva litter content in it. Hence silk warm larval litter is more affective on increasing the methane in produced bio gas.



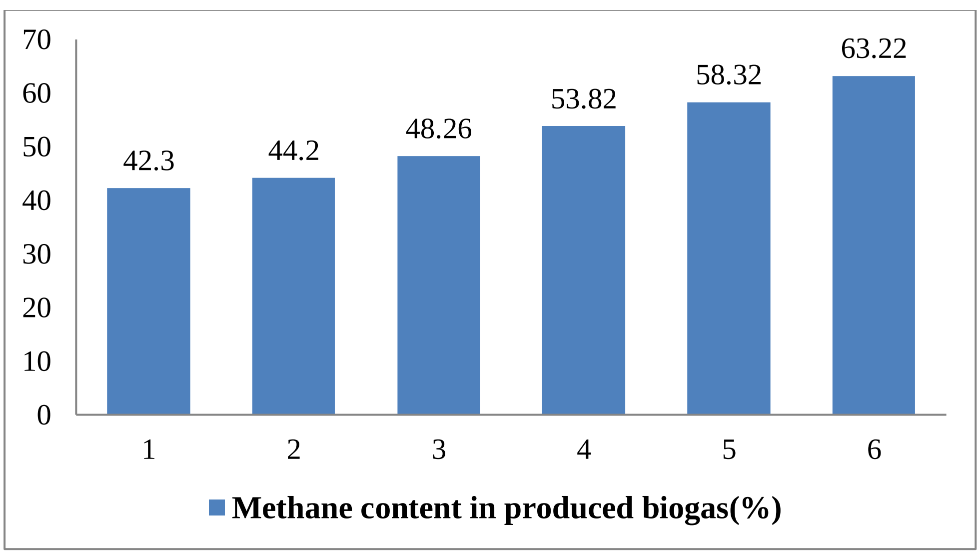
We have observed that the due to high presence of carbon up to 49.31% composition in silkworm larva litter which affect the calorific value of biogas, since in our 6th trial most of cow dung is replaced by silkworm larva litter we have high calorific of 6th trial of 6005. Hence we can say that the silk warm larval litter is more affecting on increasing the calorific value in produced bio gas.

Table 9: Comparison among various ratio of food waste in fiber composite plastic made Biogas Plant.

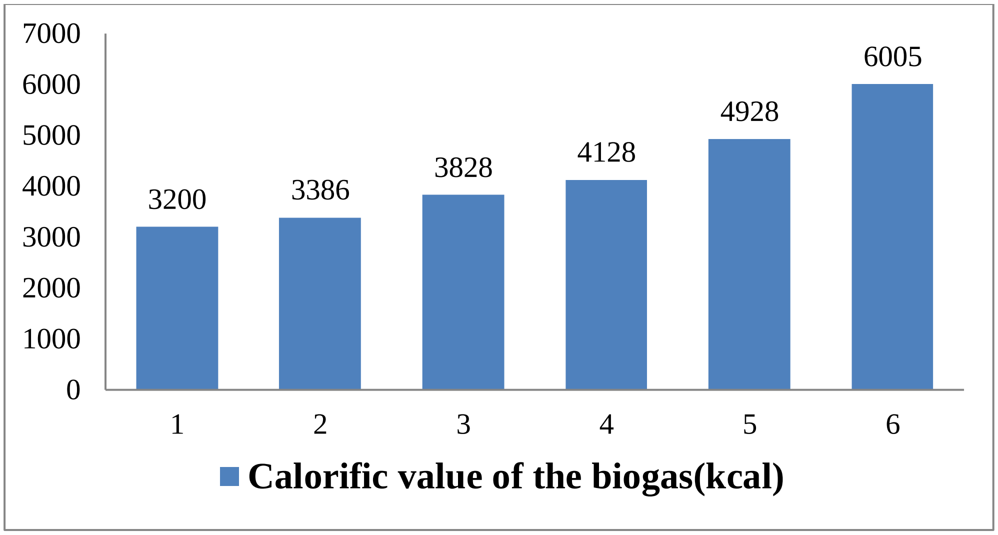
Sl no.	Total mass of slurry in the digester(kg)	Percentage of different biomass composition	Total biogas generated (m^3)	Methane gas% in the biogas	Calorific value of the biogas(kcal)
1	20	60% food waste +40% water	0.091	42.3	3200
2	20	50% food waste + 30% water + 10% urea + 10% silk worm larva litter	0.152	44.2	3386
3	20	40% food waste + 30% water + 10% urea + 20% silk worm larva litter	0.215	48.26	3828
4	20	30% cow dung + 30% water + 10% urea+ 30% silk worm larva litter	0.315	53.82	4128
5	20	20% cow dung + 30% water + 10% urea+ 40% silk worm larva litter	0.453	58.32	4928
6	20	10% cow dung + 30% water + 10% urea+ 50% silk worm larva litter	0.6821	63.22	6005



As we observed from our trials that food waste doesn't contribute much for bio gas generation but it can be used as a supporting matter due to its high content of moister since we have more generation of food waste generated in our daily life's, it can be used in particular combination with cow dung and silkworm larva litter.



Food waste has many compositions but it lacks in methane producing carbon and hydrogen atoms in its due to which methane content in methane content in our 1st trial which has 60% of food waste produce very less methane compared to other but by using it as additive in our further trials has given us good results as shown.

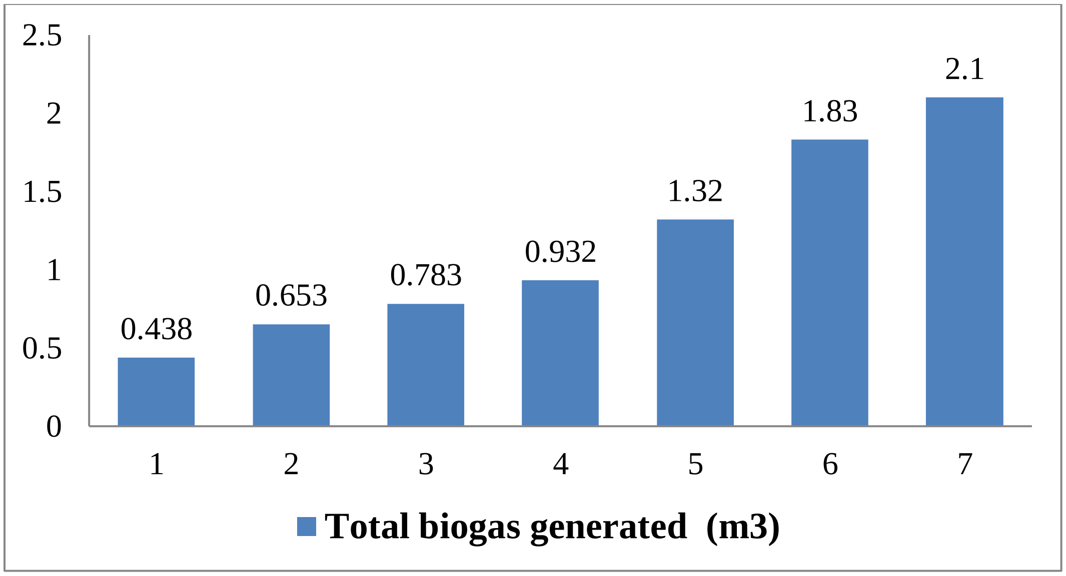


The Calorific value comparison show us the differing between our 3rd and 4th trial doesn't have a much difference as we can observe hence we can say food waste with particular composition can give us enough Calorific value for biogas which can be used for our house hold.

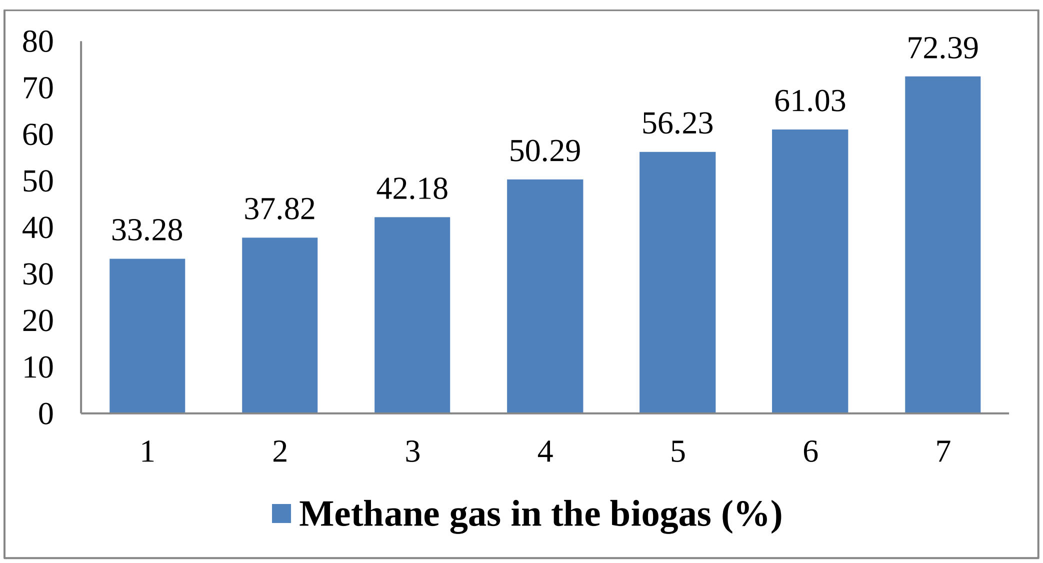
Table 10: Comparison among Various Ratio of vegetable waste in fiber composite plastic Made Biogas Plant.

Sl no.	Total mass of slurry in the digester(kg)	Percentage of different biomass composition	Total biogas generated (m^3)	Methane gas% in the biogas	Calorific value of the biogas(kcal)
1	20	60% vegetable+0% silk worm larva litter +30% water+ 10% cattle urine	0.438	33.28	3258
2	20	50% vegetable+10% silk worm larva litter +30% water+ 10% cattle urine	0.653	37.82	3380

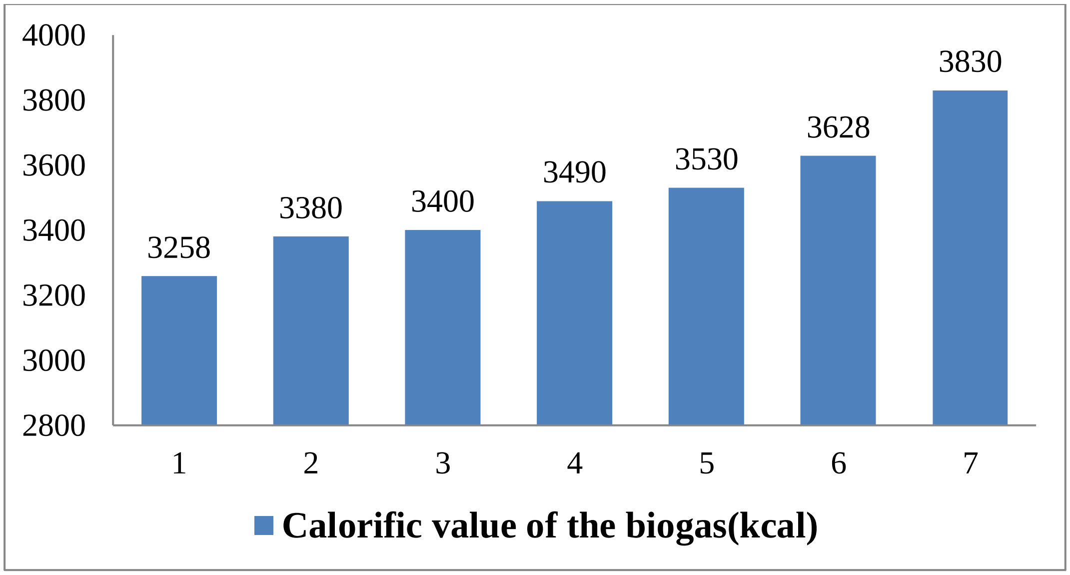
3	20	40% vegetable+20% silk worm larva litter +30% water+ 10% cattle urine	0.783	42.18	3400
4	20	30% vegetable+30% silk worm larva litter +30% water+ 10% cattle urine	0.932	50.29	3490
5	20	20% vegetable+40% silk worm larva litter +30% water+ 10% cattle urine	1.32	56.23	3530
6	20	10% vegetable+50% silk worm larva litter +30% water+ 10% cattle urine	1.83	61.03	3628
7	20	0% vegetable+60% silk worm larva litter +30% water+ 10% cattle urine	2.10	72.39	3830



We know that vegetable waste has other composition such as volatile solid, organic carbon, nitrogen and ash; this lack the digestion process but as we observe from our 4^{th} and 5^{th} trial the biogas generated has bumped up with difference of $1m^3$ from 4^{th} to 5^{th} which has 20% of vegetable waste with other composition feed into digester, hence we can say that in particular composition the vegetable waste generate good amount of biogas.



We know that vegetable are rich in cellulose, lignin and hemi-celluloses which are hydrocarbons contribute for methane content in but vegetable waste also have high moisture content that is in our 1^{st} trial due high presence of water the moisture of slurry will further increase but with increasing silkworm larva litter in our further trials the methane content in biogas has increased as we observe.



Vegetable waste also has organic carbon which can increase calorific value of biogas as we see from our 5th trial which has calorific value competitive with 6th trial with 0% vegetable, hence we can say biogas generated from vegetable waste can provide good amount of heat.

CONCLUSION

In all the trials different ratios of silk warm larval litter, cow dung, cattle urine and water mixtures produced biogas of different quantity and quality in 20L water container biogas plant. As it was observed the iterations took around 10-15 days and successfully produced biogas, that concludes that biogas can be generated on a small scale also which as effective as the conventional biogas digester. It is concluded based on the observation that the blends containing 10% cattle urine and 30% water had their Biogas generation rate, methane and calorific value relatively high with cow dung blend and cashew nut fruit blend.

As already stated in the objectives of this project, the main intension is to increase the percentage of methane in the biogas, Calorific value of biogas and to find out the reason behind high content of methane, calorific value in particular composition of slurry. For this purpose it is necessary to analyzer both biomass samples and the biogas produced from each of the composition. Ultimate analysis of biomass samples are done and the gas collected in the collection tube is directly sent to the gas analyzer where it records the percentage of methane, H_2S, CO_2, O_2, N_2, etc. present in the biogas.

REFRENCES

1. Biogas production: current state and perspectives. Peter Weiland.
2. Biogas Generation through Anaerobic Digestion Process-An Overview. Deepanraj B, Sivasubramanian V and Jayaraj S.
3. Biomass for Renewable Energy and Fuels. DONALD L. KLASS.
4. https://www.wastedive.com/news/world-bank-global-waste-generation-2050/533031/
5. eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy
6. Introduction to Biogas & Applications. N B Pruthviraj.
7. https://en.wikipedia.org/wiki/Biogas
8. Biogas for Clean Energy. Demsew Mitiku Teferra and Wondwosen Wubu
9. https://www.greenoptimistic.com/biogas-production-principle-20080206/
10. Review of factors affecting biogas production. Sithara Mary Sunny, Kiran Joseph
11. A Review on Biogas Plant. Om Prakasha, Anil Kumarb , Anukul Pandeyc, Arbind Kumara, Vinod Laguria,
12. https://energypedia.info/wiki/Types_of_Biogas_Digesters_and_Plants
13. http://www.nzdl.org
14. https://www.pinterest.com/pin/293015519490229942/
15. https://www.homebiogas.com/Blog/141/Advantages_and_Disadvantages_of_Biogas.
16. Karim. K, R. Hoffmann, K.T. Klassonb, M.H. Al-Dahhan, Anaerobic digestion of animal waste: Effect of mode of mixing, Water Research, 39, 2005, pp 3597-3606.
17. Nielsen, H.B. and I. Angelidaki. Strategies for optimizing recovery of the biogas process following ammonia inhibition. Bioresource Technology. 2008, 99(17):7995-8001.
18. Krylova, R.E. Khabiboulline, R.P. Naumova, M.A. Nagel, The influence of ammonia and methods for removal during the anaerobic treatment of poultry manure, J. Chem. Technol, 70(1), 1997, pp 99-105.
19. Effects of cycle-frequency and temperature on the performance of anaerobic sequencing batch reactors (ASBRs) treating swine waste. P.M. Ndegwa , D.W. Hamilton, J.A. Lalman, H.J. Cumba
20. Attached film media performance in psychrophilic anaerobic treatment of dairy cattele wastewater. D. R. Vartak, C. R. Engler, M. J. McFarland & S. C. Ricke.

21. Budiyono, I.N. Widiasa, S. Johari, Sunarso, The kinetic of biogas production rate from cattle manure in batch mode, Int. J. of Chem. Biological Engg., 3(1), 2010, pp 39-44.
22. VytautasKalpokas, Experimental investigations on biogas production using pig manure and slaughter house waste, Int. National Conf. on Environmental Engineering, 2011, pp 150-154
23. Anaerobic Co-digestion of Pig Manure and Spent Coffee Grounds for Enhanced Biogas Production. A. Orfanoudaki, G. Makridakis, A. Maragkaki, M. S. Fountoulakis, N. G. Kallithrakas-Kontos, T. Manios.
24. Studies on the Effect of Urine on Biogas Production. M. Shamsul Haque and M. Naimul Haque.
25. Improving biogas yield by anaerobic co-digestion of chicken litter with grass silage and treating with fungal enzyme cocktail. Navodita Bhatnagar, David Ryan, Richard Murphy, Anne-Marie Enright.
26. Dahunsi, S. Mechanical Pretreatment of Lignocelluloses for Enhanced Biogas Production: Methane Yield Prediction from Biomass Structural Components. Bioresour. Technol. 2019, 280, 18–26.
27. Semi-continuous anaerobic co-digestion of vegetable waste and cow manure: a study of process stabilization. L. R. Miramontes-Martínez, R. Gomez-Gonzalez, J. E. Botello-Álvarez, C. Escamilla-Alvarado, A. Albalate-Ramírez and P. Rivas-García.
28. Biogas production from food waste via co-digestion and digestion effects on performance and microbial ecology. Mirzaman Zamanzadeh, Live Heldal Hagen, Kine Svensson, Roar Linjordet & Svein Jarle Horn.
29. The biogas production potential from silkworm waste. Małgorzata Łochyn´ ska, Jakub Frankowski.