FACULTY OF PUBLIC HEALTH AND INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE & TECHNOLOGY

RECOVERABLE POTENTIAL OF ELECTRIC ENERGY FROM BIOGAS PRODUCED ANAEROBIC DIGESTION OF FOOD WASTE: THE CASE OF JIMMA UNIVERSITY.

BY

KIFLE KEBEDE

ARESEARCH THESIS SUMMITTED TO DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY, FACULTY OF PUBLIC HEALTH AND INSTITUTE OF HEALTHSCIENCES, JIMMA UNIVERSITY IN PARTIAL FULLFILLMENT FOR THE REQUIREMENT OF MASTERS DEGREE IN ENVIROMENTAL HEALTH SCIENCE AND TECHNOLOGY.

August, 2018

Jimma, Ethiopia

RECOVERABLE POTENTIAL OF ELECTRIC ENERGY FROM BIOGAS PRODUCED ANAEROBIC DIGESTION OF FOOD WASTE.

By

KIFLE KEBEDE

ADVISORS:

1. Alemayehu Haddis (PhD)
2. Samuel Fiekadu (MSc. PhD Candidate)

August, 2018

Jimma, Ethiopia

Approval Sheet

I, the undersigned, declare that this research paper is my original work and has not been presented for the award of a degree in any university and all the sources of materials used for this thesis have been properly acknowledged.

Kifle Kebede ______________ ______________

Signature Date

Approval of the advisors:

Approved by

Signature Date

1. Alemayehu Haddis (PhD) ____________ _________

2.Samuel Fiekadu (MSc.PhD Candidate) ___________ _____________

Department Head:

3. Embialle Mengiste(phD) ___________ ___________

Jimma University

Institute Of Health Science, Faculty of Public Health

Department of Environmental Health Science and Technology

Environmental Health Science and Technology (MSc) Program

Board of Examination Thesis Approval Sheet

Members of Board of Examiners

External Examiners ------------------- Signature----------- Date--------

Internal Examiners--------------------- Signatures------------ Date--------

Moderator------------------------------ signatures----------- date---------

ABSTRACT

Food waste (FW) getting changed into biogas not only becomes an alternative resource of energy but also helps in reducing the methane fabrication which is one of the green house gases that cause global warming. In this research the estimation of FW generation rate is the initial steps work when considering the energy recover through the Anaerobic Digestion (AD) method. The aim of this study is to investigate the recoverable potential of electric energy from FW. FW is obtained from Jimma University student cafeteria and specialized hospital. Two fabricated laboratory-scale digesters were used to digest the FW with different concentration of moisture (H_2O) content and also by adding inoculates as a microbial sources and catalyst by using AD technology through batch reactor process systems and mesophilic type temperature conditions Experimental analysis was conducted. The water displacement method was used to investigate the volume of biogas produced and methane gas identification was done through biogas analyzer machine. The total production rate of biogas was found to be 260.18ml/225g of waste within 70% of H_2O content in a day, which was produced large biogas whereas it was 188.9 ml/150g with an average production rate in a day with 80% of H_2O content and it was less biogas production. In general, the study was estimate FW generation rate from Jimma University which account to 2.036tonns/day and 752.558tonnes/year. Biogas production from FW through an AD of 5L capacity digester in the lab scale was evaluated for 23 days. The total amount of biogas production recorded was about 2463ml (58.16% CH_4) in reactor1 and 2266.5ml(55.07%CH4) in reactor 2 which can recover 0.053kwh/day(i.e 19.4kwh/year) and 0.0043kwh/day (i.e. 1.57kwh/year) electrical energy respectively. Based on this we can recover electrical potential energy which accounts to 17677.89kwh/d and 6452428.35kwh/y from752.558tones/y FW. Finally it recommend that large FW generation disposed to land fill can be converted to biogas through mono-AD process as alternative sources of electrical potential energy recoverable which can reduce scarcity of electrical energy supply and LPG costs, which is mandatory to sustainable development of social, economical and environmental feasibility.

Key words: Food waste, Anaerobic Digestion, Biogas, Electric potential.

ACKNOWLEDGEMENT

First of all I want to thank the Almighty God. Next I would like to acknowledge my advisors Dr.Alemayehu Haddis and Mr.Samuel Fiekadu for their unreserved encouragements and provision of constructive comments and guidance while preparing this thesis. Also my special gratitude goes to my family specially,Degu Kebede for their unconditional support and encouragement.

Furthermore, Jimma University Faculty of Public Health and Institute of health Sciences Department of Environmental Health Science and Technology is properly acknowledged for giving me this golden and educating opportunity. I would also thank Gindo secondary school administration and chemistry department teachers for their encouragement. Last but not least I would like to express my deep appreciation to my lovely Simegn Tsegeye who is hope, pleasure, help and encouragement in my entire journey.

Abbreviation or Acronym

ABP- Animal By-Products

AD –Anaerobic Digestion

FW-Food Waste

GHG- Green House Gases

GWP – Global Warming Potential

IPCC – Intergovernmental Panel on Climate Change

ISO – International Organization of Standardization

LCA – Life Cycle Assessment

LHV- Lower Heating Value

LPG- Liquid Petroleum Gas

MSW- Municipal Solid Waste

OFMSW – Organic Fraction of Municipal Solid Waste

THP - Thermal Hydrolysis Process

WWS- Waste Water Sludge

pH – Power of hydrogen

Table of Contents

List of figure

List of Table

CHAPTER ONE

1. INTRODUCTION

1.1. BACK GROUND OF THE STUDY

Energy is one of the most important factors to global wealth. However the over dependences on fossil fuel as primary energy sources has led to global climate change, environmental pollution and degradation, thus leading to human health. The majority of people in developing countries do not easily and progressively have access to advanced form of energy such as electricity; therefore, they entirely depend on 60% of wood fuels like fire woods and charcoal to meet their basic energy needs for cooking and lighting. This has resulted in depleting forests at a faster rate than they can be replaced (Gashaw, 2016).Biogas is a well established fuel that can even replaced wood as energy sources for cooking and lighting. The amount of municipals solid waste(MSW) generated and energy requirements are serious problems due to rapid urbanization, industrialization and population increments, which to reach 9.5 billion by 2050,Food Waste(FW) makes a dominant contribution to MSW (25–70%) (Pham *et al.*, 2015) .

FW is the second huge amount of MSW going for dumping and currently, only about 2.5% of FW is recycled yearly making landfills the third major resource of methane and the principal technology is composting, (Chesshire, 2013; Karagiannidis, 2012). About one-third of rations prepared for human being utilization is vanished globally, which accounts to regarding 1.3 billion tons per annum (Batori and Nair, 2017). whereas allowing for the worldwide FW generation per annum,over 7.3 million tons in Australia in 2008, 7,000 to 15,000 tons of post-consumer FW in California was collected(US-EPA, 2014). 50 million tons per annum In Indian (Velmurugan and Ramanujam, 2011).Ethiopia produces a plenty of fruits and vegetable wastes and generates a solid waste of 0.4 kg/capita/day in Addis Ababa only (Gashaw, 2016). Organic waste such as FWs not only visual discomfort by producing different moldering gases and offensive odors(Noxious smell), but also cause adverse environmental impacts due to leaching in landfill sites, worsening of water quality, ecological stress and strain, imposes risks on the world food security, contributes methane (CH4)and Nitrous Oxide (N_2O), which have 21 and 310 times greater dangerous or global warming potential (at trapping heat in the atmosphere) respectively than carbon dioxides (Pham *et al.*, 2015; Batori and Nair, 2017). In recent years, it has been recognized that FW is an unexploited resource with large potential for generating energy. This realization has motivated fundamental research on technologies that help to recover some valuable fuels from FW to reduce the environmental burden of its disposal, avoid reduction of natural resources such as petroleum and fossil fuels, minimize risk to human being health and sustain an overall balance in the ecosystem(Pham *et al.*, 2015; Mustafa, Calay and Román, 2016).

Anaerobic Digestion Bio Waste Treatment Technology

Anaerobic Digestion is a biological procedure, which reduces organic pollution and yield renewable energy (biogas).Bioprocess is regarded as an optional energy source to fossil fuel(Liu *et al.*, 2018).There are different new technologies that used to optimizing an available energy resources. Some of the sources are a) Wind energy b) Bio mass c)Solar energy d) Geo thermal energy. Biogas is defined as the gas formed by the process of decomposing organic matter in the absence of oxygen. AD is one of the favored technologies for treating residential waste in which varieties kind of microbes decomposing an organic matter, such as food ravage, dung, and sewage sludge in the absence of oxygen for the fabrication of biogas which comprising mainly CH_4 and CO_2, and other traces gases such as, oxygen (O_2) and hydrogen sulfide (H_2S) (Khalid *et al.*, 2011). Hence methane gas can be used as other energy to liquid petroleum gas (LPG) and natural gas. The residue, after completion of the AD route, is a stabilized organic material that can be useful directly on agricultural land (without any maturing) as a bio-fertilizer, and thereby can replace artificial/mineral fertilizers and offer the possibility for recycling of nutrients (nitrogen and phosphorus) (Batori and Nair, 2017). Biogas can be used as fuel in any country for heating purposes, such as cooking and more. It can also be used in anaerobic digesters where it is typically used in a gas engine to convert the energy in the gas into electricity and heat.Biogas is a renewable fuel so it qualifies for renewable energy subsidies in some parts of the world(M.A.O. Mydin *et al.*, 2014).

There are four type biological and chemical steps of AD for Biogas invention: Hydrolysis, Acidogenesis,Acetogenesis and Methanogens (Onojo *et al.*, 2013).Methanogens is responsive to both high and low pH and can survive between pH 6.5 and pH 8 (Onojo *et al.*, 2013)

In AD systems, methane fermentation takes place within the pH 6.5 to 8.5 ranges and highest gas assembly in the optimal range from7.0to8.0 (Perkoulıdıs and Moussıopoulos, 2017).The fall of pH during the earliest few days of digestion due to the high volatile fatty acids formation. This paper aims to identify the potential recoverable of biogas generation from FW. Which is equivalent to mega watt (MW) or KW electricity can be produced yearly based on FW generated on year 2018 in case of Jimma university student cafeteria and Hospital.

Quality and quantity of biogas will be affected by many parameters including pH, temperature, feed composition, loading rate, mixing condition, reactor design, and residence time, solid content.

Electricity and heat energy generation from biogas varies depending on the methane content of the biogas. However, the major problem is the long duration of the microbial reaction, which is generally in the range of 20–40 days (Pham *et al.*, 2015).

This study deals with estimating the amount of biogas produced, through the lab scale setups, using the mixed FW (left over after consumption) produced in Jimma University. The proper management of FW in Jimma university is big problem and remedy for this may be the production of biogas which will be done in eco-friendly and cost effective way.

The study was performed in two different concentrations of the FW and moisture content in two different proportions set-up of 5 liter Edibon anaerobic digester machine; in-order to find the maximum biogas and methane production.

1.1. Statement of the problem

As reported by Aremu and Agarry (2013) the planet will have 9 to 10 billion inhabitants number in the year 2040 that can produce trash and need power supply and wealth. This outcome rapid enlargement of population and unrestrained urbanization which causes energy crisis, generate millions tones of wastes, shortage of final ravage dumping and increase environmental and communal fitness problems .The recent rise in oil and natural gas costs and problem connected fossil fuels are also the other problems of our globes.

The carbon footprint of FW is estimated to be 3.3 billion tons of CO_2 equivalents per year of GHG released into the atmosphere. Similarly, 1.4 billion hectares of land 28 %t of the world's agricultural area is used each year to produce food that is lost or wasted. It is estimated that while about 870 million people are reported to be chronically undernourished (Batori and Nair, 2017).Inappropriate management and disposal of FW due to population growth can have negative influences on human and environmental health during the decomposition process (Genet, Wolka and Melaku, 2015).In Ethiopia's fuel wood is over harvested in many areas, contributing to deforestation of already ecologically sensitive areas; fuel wood and charcoal have been and are rapidly becoming more expensive (Getachew *et al.*, 2006).

The research conducted in Jimma town(mokenin; 2017) on biogas potential from the co digestion of FW with cow dung and khat, however didn't assess, biogas production from monodigestion postconsumer mixed FW recoverable of potential electrical energy. Therefore, this study focused on recoverable potential of electric energy from FW. The case of Jimma University compound, where this study was carried out, student cafeteria and hospital FWs have been deposited to landfill. This creates soil and ground water can be contaminated, negatively influencing soil quality and aquatic ecosystems. Neighborhood pride is affected due to unpleasant visual appearances of the environment and offensive smells while opportunity for wild and house hold animals (dogs, cats, apes, vouchers, eagle and different birds, etc.) to scavenge the material and become accustomed to this food source. Wildlife biologists state that human food is not necessarily good for wild animals due to discarded food can become contaminated with microorganisms that cause food poisoning(Genet, Wolka and Melaku, 2015).At this University, significant volumes of FWs has been produced daily, but no study concerning the productive utilization and safe disposal mechanisms for this material has been implemented. The plant for the treatment of FW generation through AD has not been sufficiently studied to suggest a more productive use for it besides threatening the health of ecosystems and degrading environmental quality. In generally there are:

1.2. Significances of the study

One requirement for sustainable improvement is the adequate energy services for satisfying basic needs, improving social welfare, and achieving fiscal development. Consequently, the challenge of energy for sustainable development will require uninterrupted effort on the part of international organizations, national governments, the energy community, civil society, the private sector and individuals. Based on the result obtained from this study the importance of FW produced in Jimma university conversion to electric potential recover of energy are;

Beneficial to reduce large amount of FW disposed to land fill per a year from Jimma University. It can be reduce electric energy scarcity occurrences, environmental and human health problems and land scarcity, fewer kilometers driven.

It used to mitigate vector born disease breeding like rat, mosquito and fly in Jimma University.

It used to alleviate house hold and wild life FW scavenger in Jimma University.

It used to insight Ethiopian Environmental Protection Authority, possibility to recover electrical energy from food waste that results to socioeconomic and environmental feasibility.

The study results is also used as base line for the further research on the recoverable of electrical energy from liquid and solid organic waste lost from Jimma university.

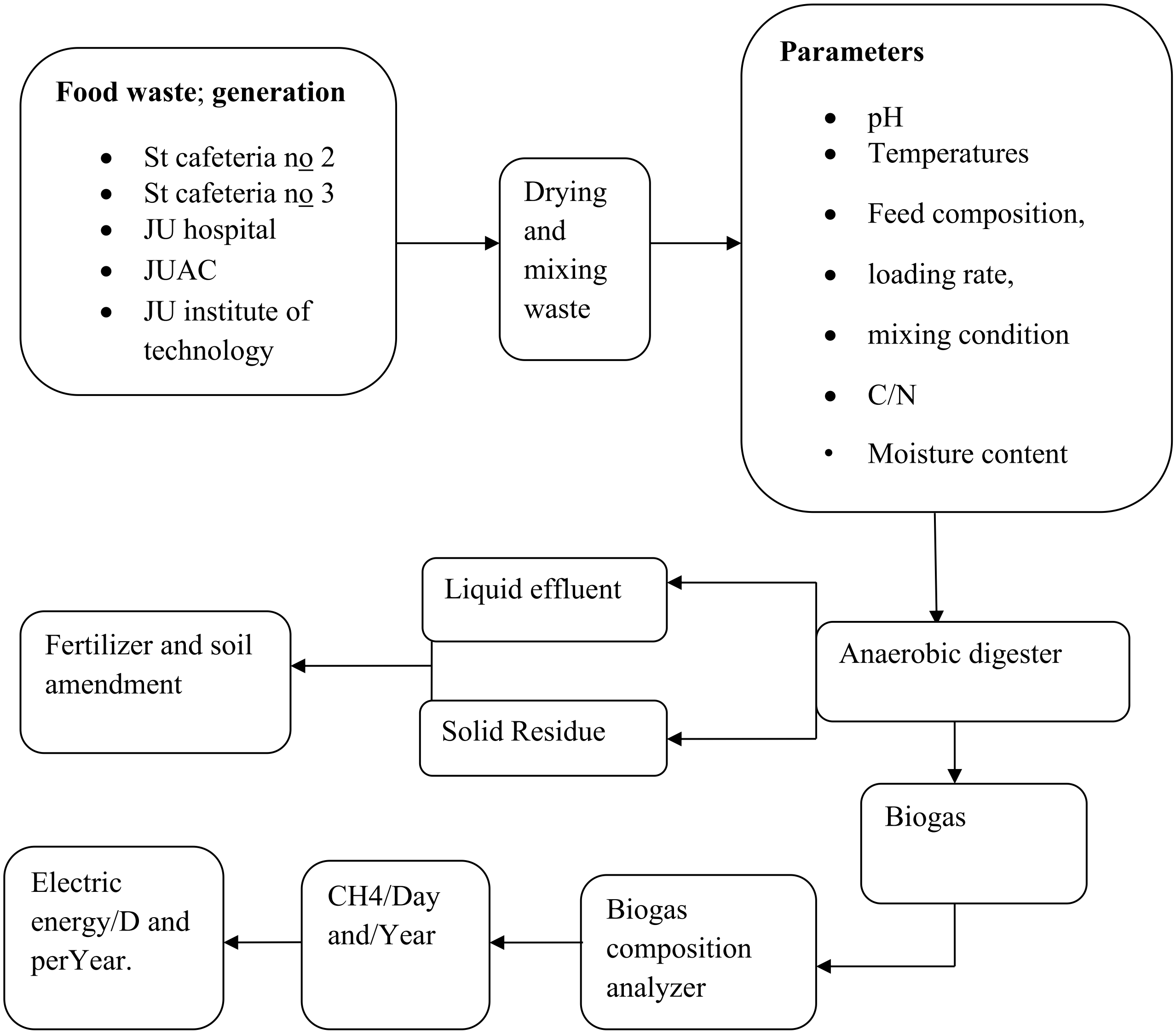

Figure 1: Conceptual frame work of biogas production from FW.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Potential substrates for biogas production

FW is the organic material having the high calorific rate and nutritive value to bacteria. In most of cities and places, FW is disposed in the landfill or discarded, which causes the public health hazards and diseases like malaria, cholera. Inadequate executive 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 an unpleasant odor and methane which is a major GHG contributing to global warming (Awasif, Maskhoot and Saadi, 2016).According to Batori and Nair, (2017) the causes of food losses and waste in both industrialized as well developing countries are:

a. Food gets lost when production exceeds demand.

b. ‘Disposing is cheaper than using or re-using’ attitude leads to FW

c. High ‘appearance quality standards’ from supermarkets for fresh products

d. Wide range of products/ brands in supply

Biogas can be formed from various types of biomass containing carbohydrates, proteins, fats, cellulose, and hemicelluloses as the main components. Lignin rich matters (e.g. wood) are unsuitable for biogas invention due to their slow degradation rate in anaerobic situation. Due to the change of substrates as well as variable method parameters and retention time in the bioreactor, the chemical composition and yield of biogas are subject to variations.

2.2. Characteristics of biogas

Biogas technology is a low cost fuel with manufacture of a useful soil amendment, improved urban sanitation, and low gestation period, provision of fast profit, participant friendliness and political acceptance. Biogas technology is a socially relevant, useful, economically viable and financially sound energy source that provides energy security to developing economies (Somashekar, Verma and Naik, 2014).Biogas is a by-product of the biological crash under the oxygen- free conditions of organic wastes such as plants, crop residues, fish residues, wood and bark residues, and human and animal droppings.Methane is a spotless energy one of the constituent of biogas which has a great potential to be an alternative fuel (Mohan and Jagadeesan, 2013).

The content of biogas vary based on the degradable material as well as procedure situation e.g. temperature .The production of biogas is done by the AD biodegradable substances like dung, green waste, sewage, plant material, municipal waste and crops. The general composition of biogas is Methane gas- 55-70%, Carbon dioxide gas- 30-45%, Hydrogen Sulfate- 2-8% (Muthu *et al.*, 2017).

Methane is the energy carrier of biogas; therefore a high methane content rather than CO_2 content is desirable for energy production. Composition of biogas while depends upon feed material. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750 ^{0}C.An odorless & colorless gas that burns with blue flame similar to LPG. The average calorific value of biogas is about 22-24.5 MJ/m^3 and it usually burns with 60 % efficiency in a conventional biogas stove, so that 1 m^3 of biogas corresponds to 0.55-50.65diesel fuel which is about 6 kWh (Muthu *et al.*, 2017).The concentration of water vaporizes from 2–7 volume% depending on the temperature of digestion. from vary feeding processes with the loading rate of 1/4 showed that the highest biogas amount formed and most capable energy rate is developed during treatment (36-40°C, with the stirrer) (Ahamed, Raiyan and Hossain, 2016).

For biogas storage, safety regulations, such as explosion control and safety zones, must be followed due to the flammable nature of biogas.

Methane is the main constituent of natural gas which is relatively clean flaming, colorless, and odorless. This gas can be captured and burned for cooking and heating that are being done on a large scale in some countries of the world (Ahamed, Raiyan and Hossain, 2016).

2.3. Anaerobic Digestion (AD)

AD or mechanization is a biological process in which organic compounds are transformed into carbon dioxide and methane (biogas) by micro organisms in the absence of oxygen. These processes represent a promising technology for treating liquid and solid waste while producing valuable energy and limiting the greenhouse (Ghouali, Sari and Harmand, 2015).The system stability and procedure performance of anaerobic reactors mainly depend on many parameters and situation such as temperature, pH, carbon to nitrogen ratio (C/N) and feed-stock to micro organism ratio (F/M) have their own roles in AD process(Liu *et al.*, 2018).

It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutrias effluents. The main advantage in using AD is the biogas production, which can be used for steam heating; cooking and generation of electricity. A major limitation of AD of vegetable wastes is the rapid codification due to the lower pH of wastes and the larger production of volatile fatty acids (VFA), which reduce the methanogenic activity of the reactor (Velmurugan and Ramanujam, 2011).Clostridium microbial species are most common among the degrade under anaerobic condition(Khalid *et al.*, 2011).

The AD is a renewable energy resource because the route produces a methane and carbon dioxide rich biogas proper for energy manufacture which helps to substitute fossil fuels. Also, the nutrient-rich solids left after digestion can be used as fertilizers (Ahamed, Raiyan and Hossain, 2016).while also represents an opportunity to decrease environmental pollution odors, the spread of pathogens and dieses, antibiotics, and greenhouse gas emissions(Overview, 2015).AD is becoming more and more attractive for the handling of high strength organic wastes such as swine manure, since it produces renewable energy, methane, and valuable digested residues, liquid fertilizer and soil conditioner (Muršec and Vindis, 2010).

Organic waste can differ very much even in same geographical areas, therefore it is strongly recommended to conduct laboratory before design of the full scale digester is made. Considering the costs of the full scale digester, conducting pilot scale experiments is a minor item, especially if you have no preceding results or experience (Zupančič and Grilc, 2007).

The digestion process can be divided into solid (dry) digestion and wet digestion processes. Dry systems contain 30–40% dry matter where as wet systems contain 10– 25% dry matter(Khalid *et al.*, 2011)**.**Solid digestion processes are in fact anaerobic composers. In this process substrate and biomass are in presoaked solid form, containing 20 % of dry matter and 80 % water. Such processes have several advantages. The main advantage is reducing the reactor volume due to much less water in the system. Four times more concentrated substrate equals approximately four times less reactor volume. It is also possible that some inhibitors (such as ammonium) can have less inhibitory effects in solid digestion process. The biggest disadvantage of solid digestion process is the substrate transport. Substrate in solid form requires additional energy for move in and out of the digesters. It is also a stronger possibility of air interference into the digesters, which poses a great risk to process stability and safety.

The AD is occurring under mesophilic conditions (approximately 35°C) and the average retention time in the two-stage process is 18–20 days. The created biogas is purified and injected in the natural gas grid (Holliger, Fruteau de Laclos and Hack, 2017). Mesophilic digesters have longer retention time (10-40 days) (Arsova, 2010).EU policies concerning renewable energy have set forward the duty of supplying 5% of the European energy demands from AD biogas by year 2020 (Batori and Nair, 2017).

2.4. Processes of biogas production

According to **Ziauddin and Rajesh, (2015)**there are four key biological and chemical stages of AD.

Hydrolysis; Is the first stages the organic matter is enzymolysed outwardly by extracellular enzymes, cellulose, amylase, protease & lipase, of microbes. Microorganisms crumble long chains of complex carbohydrates, proteins, & lipids into small chains. For example, Polysaccharides are transformed into monosaccharide. Proteins are changed into peptides and amino acids. Where complex organic molecules (cellulose, proteins and fats) are broken down into simple sugars, amino acids, and fatty acids by hydrolyses an exoenzyme. Hydrolysis of carbohydrates takes place within a few hours while proteins and lipids take a few days to break down(Mustafa, Calay and Román, 2016).

Group of microorganisms such as actinomyces, Thermomonospora, Ralstonia and Shewanella are involved in the degradation of FW into volatile fatty acids (Khalid *et al.*, 2011).

Acidogenesis or formation of organic acids; The monomers formed in the hydrolytic phase are taken up by acidogenic bacteria to be further degraded into short chain organic acids, alcohols, hydrogen and carbon dioxide.

Acetogenesis: In this step, acetogenic micro-organisms more decaying the H_2 and CO_2 gas to make mostly acetic acid and organic acids and alcohols which are consequently changed into acetate. The acetate serves as a substrate for methane-forming germs and the acetogenic bacteria, which grows in a synergetic bond with methane forming bacteria.

Methanogenesis

Bacteria known as methanogens, change the acetic acid into methane, CO_2 and water under severe anaerobic situation. The complex organic resources are decomposed by acidogenic germs to volatile fatty acids and alcohols, which are then easily metabolized into CH_4 and CO_2 by methanogens or archaea while a set of microorganisms such as Methanosarcina and Methanobrevibacter/Methanobacterium mainly contribute in methane production (Khalid *et al.*, 2011).

Methane-producer bacteria, which were concerned in the third step, grind compounds having small molecular weight. They exploit hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural situation, CH_4 producing microorganisms occur to the level that anaerobic situation are provided, e.g. under water (for example in marine sediments),and in marshes. They are basically anaerobic and very susceptible to environmental changes, if any occurs. The methanogenic bacterium belongs to the archae bacteria genus, i.e. to a group of bacteria with heterogeneous morphology and lot of common biochemical and molecular-biological properties that distinguishes them from other bacteria. The focal difference lies in the structure of the bacteria's cell walls. A nutrient-rich by-product, known as the digestive, is formed during this process.

In generally biochemical stage of AD according to Anaerobic Treatment and Biogas Production from Organic Waste (Zupančič and Grilc, 2007).

Table 1:Regeneration time of microorganisms

Microorganisms	Time of regeneration Less
Acidogenic bacteria	Less than 36 hours
Acetogenic bacteria Methanogenic	80-90 hours
Methanogenic archaea	5-16 days
Aerobic microorganisms	1-5 hours

2.5. Factors influencing AD, biogas yield and production

According to Khalid *et al.*, (2011).The biogas yield is impacted by many factors including type and content of objects, microbial masterpiece, temperature, wetness and bioreactor design, Acidity and alkalinity (pH value) of materials and organic loading rate may affect biogas productions influent rate and methane concentration in a positive manner, Moreover, fabrication of larger volatile fatty acids from such waste under anaerobic situation inhibits the activity of methanogenic bacteria (Perkoulıdıs and Moussıopoulos, 2017).

The addition of co-substrates such as abattoir waste water and activated sludge to fruit and vegetable waste can improve biogas invention up to 52%.moreover, the environmental necessities of acidogenic bacteria differ from requirements of methanogenic archaea. Provided that all steps of the decomposition route have to take place in a single digester (one-stage process) usually methanogenic archaea requirements must be considered with priority. Namely, these organisms have much longer restoration time, much slower growth and are more responsive to environmental situation then other microbial present in the mixed culture. Methanogenesis is beside other factors - susceptible to both high and low pH values and performs well between pH 6.5 and pH 8 (Zupančič and Grilc, 2007).

2.5.1 Pre-treatment.

Pre-treatment is the case to reduce solids size, separate the non-digestible solids (soil, stones, plastics, metals...) should be alienated from the materials flow in the first step. Pretreatment can be made by physical, chemical or combined means.

Physical pretreatment; the best known disintegration process are grinding and mincing. In grinding and mincing the energy required for process is inversely relative to the particle size. the recommended final particle size is 1–2 mm for effective decomposition. Size decline increases the total hydrolysis yield by 5–25 %, and also reduces the digestion time by 23–59 % (Krátký, Jirout and Nalezenec, 2012).

Chemical pre-treatment can be used when treating ligno-cellulosic material, such as spent grains or even silage. Very often chemical treatment is used combined with heat, pressure or both. It is common to use acid (hydrochloric, sulphuric or others) or an alkaline solution of sodium hydroxide (in some cases soda or potassium hydroxide), When pH<6, a 1 M $Na2HCO_3$ solution is added into the reactor to avoid the inhibition of methanogenesis occurring under acidic conditions (Al-Zuahiri *et al.*, 2015). Such solution is added to the substrate in quantities that surpass the titration equilibrium point and then it is heated to the desired temperature and possibly pressurized (Zupančič and Grilc, 2007). Consequently, various physical, chemical and enzymatic pre-treatments are required to increase substrate solubility and accelerate the bio- degradation rate of solid organic waste (Khalid *et al.*, 2011).

2.5.2 Temperature

AD can operate in a broad variety of temperature. Generally there are three extensively known and recognized temperature ranges of operation:

Psychrophilic (15-20°C), mesophilic (30-40°C) and thermophilic (50-60°C) it is advised that temperature fluctuations in thermophilic range should be no further than ±1°C. In mesophilic range the microbes are less sensitive; therefore fluctuations of ±3°C can be tolerated (Zupančič and Grilc, 2007).

Many Lower temperatures among the process are known to reduce microbial growth, material employment rates, and biogas manufacture. in addition, lower temperatures may also effect in an tiredness of cell energy, a leakage of intracellular substances or completely. In contrast, high temperatures minor biogas yield due to the creation of volatile gases such as ammonia which obstacles methanogenic activities.

The operation of AD at mesophilic temperatures is more stable and requires less energy expenditure than thermophilic temperature. Moreover, the advantages of the mesophilic process indicate that there is less probability of ammonia and long chain fatty acids (Liu *et al.*, 2018).The best operational temperature was 35^0C with an 18 day digestion period while a little fluctuation in temperature from 35 ^{0}Cto30 ^{0}C caused a reduction in the rate of biogas production. Overall, a temperature range between 35– 37^0C is careful suitable for the production of methane and a change from mesophilic to thermophilic temperatures can cause a sharp decrease in biogas production until the necessary populations have increased in number, for bio degradation, the temperature must be below 65 ^{0}C because above 65^0C denature of enzymes occurs(Khalid *et al.*, 2011).

However, thermophilic AD have certain advantages, such as a faster degradation(higher metabolic) rate of organic waste, less effluent viscosity and higher pathogen destruction, volatile solids and COD removal, and yields higher biogas volume compared to mesophilic treatment and numerous limitations of the thermophilic process are higher sensitivity to operational conditions, decreased stability due to the accumulation of ammonia and volatile fatty acids (prop ionic acid), lower methane content in biogas and higher net energy input(Liu *et al.*, 2018). The optimal growth temperatures for some methanogenic bacteria: 37–45^OC,for mesophilic Methanobacterium37–40^oC, for Methanobrevibacter 35–40^oC, for Methanolobus, Methanococcus, Methanoculleus, Methanospirillum and Methanolobus, 30–40^oC,for Methanoplanus and Methanocorpusculum and 50–55^oC for thermophilic Methanohalobium and Methanosarcina (Khalid *et al.*, 2011).

2.5.3. pH

If the pH decreases below 6.5, more acids are produced and that leads to imminent process failure. In real digester systems with suspended biomass and substrate containing suspended solids, normal pH of operation is between 7.3 and 7.5. When pH decreases to 6.9 already serious actions to stop process failure must be taken.

Addition of certain substrates which some contain alkaline substances to the substrate the buffering capacity of the system can be increased.

Typical are slaked lime ($Ca(OH)_2$), sodium carbonate (Na_2CO_3) or sodium hydrogen carbonate ($NaHCO_3$), and in some cases sodium hydroxide (NaOH) (Zupančič and Grilc, 2007).

NaOH & $NaHCO_3$ added to slurry for the purpose of increase/adjust pH value at optimum range (Ziauddin and Rajesh, 2015).

Although it has been proven that the optimal range of pH for obtaining maximal biogas yield in AD is 6.5–7.5, the range is relatively broad in the plants and the optimal value of pH varies with substrate and digestion technique(Arsova, 2010).

A range of pH values suitable for AD has been reported by various researchers, but the optimal pH for methanogenesis has been found to be around 7.0(Khalid *et al.*, 2011)

pH in the range of 6.8 to 7.4 should be maintained in the AD process, which is the optimum range for methanogens growth (Velmurugan and Ramanujam, 2011).

The hydrogen production will be at a maximum if the initial pH of a bio system is maintained at 9. The most favorable range of pH to attain maximal biogas yield in AD is 6.5–7.5.(Khalid *et al.*, 2011)

2.5.4. Moisture

High wetness contents usually facilitate the AD; however, it is difficult to maintain the same availability of wet throughout the digestion cycle. Initially water added at a high rate is dropped to a certain lower level as the process of AD proceeds. High moisture contents are likely to affect the process performance by dissolving readily degradable organic matter. Bio conversion processes are suitable for wastes containing moisture content above 50% than the thermo-conversion processes. Vegetable wastes, due to high biodegradability nature and high moisture content (75 – 90%) seemed to be a good substrate for bio-energy recovery through AD process (Velmurugan and Ramanujam, 2011).

It has been reported that the highest methane production rates occur at 60–80% of humidity(Khalid *et al.*, 2011). Studied methanogens processes during AD at different moisture levels i.e., 70% and 80%. However, bio reactors under the 70% moisture regime produced a stronger leachate and consequently a higher methane production rate. At the end of the experiment, 83 ml methane per gram dry matter were produced at the 70% moisture level, while 71 ml methane per gram dry matter were produced with the 80% moisture.

Biodigesters are also classified as ‘‘wet’’ or ‘‘dry’’ solid waste.wet bio reactors have total solids of 16% or less, while dry bio-reactors contain 22–40% total solids, with the intermediate rating termed ‘semi dry’, while according to dry systems contain 30–40% dry matter where as wet systems contain 10– 25% dry matte (Al-Zuahiri *et al.*, 2015).

Moisture content is one of very vital parameter affecting AD of solid wastes. There are two main reasons i.e., (a) Water makes possible the movement and growth of bacteria facilitating the dissolution and transport of nutrient and (b) water reduces the limitation of mass transfer of non-homogenous or particulate substrate. In general, the moisture content of the dig estate enlarged with increase in the amount of VS and TS decline. The moisture content to be maintained for the digestion based on the type of the waste (Somashekar, Verma and Naik, 2014).

2.5.5. Carbon

Carbohydrates are the main components of organic wastes from agriculture-related factories, FW and composed organic fraction of municipal solid waste (OFMSW) from households and markets. The anaerobic degradation of such wastes is muscularly dependent on the ratio between the acidification process rate and the methanogenic process rate (Esposito *et al.*, 2012).

Due to its rich abundance in carbohydrates such as lignocellulose, FW has been generally regarded as the carbon-rich material should be combined by nitrogen-rich (protein rich) materials (Holliger, Fruteau de Laclos and Hack, 2017).

The rate of AD is strongly affected by the type, accessibility and complexity of substrate. Different types of carbon source support different groups of microbes. Before starting a digestion process, the material must be characterized for carbohydrate, lipid, protein and fiber contents. Lipids are attractive for biogas manufacture due to the high number of C and H atoms in their molecule, which implies a high theoretical methane potential. However, they can also present several problems such as removal of methanogenic bacteria and adsorption onto biomass that can cause sludge flotation and washout (Esposito *et al.*, 2012).

Carbohydrates are considered the most vital organic component of municipal solid waste for biogas production. However, starch could act as an effective low cost material for biogas invention compared to sucrose and glucose It was reported that the initial deliberation and total solid content of the substrate in the bioreactor can drastically affect the performance of the process and the amount of methane formed among the process.

2.5.6. Nitrogen

Wastes rich in proteins and consequently with high nitrogen content are mainly formed by meat processing factories, slaughterhouses and farms (animal slurry and manure)(Esposito *et al.*, 2012). These wastes present a high organic content, high biological oxygen demand (BOD) but low C/N ratio.

FW contained a sufficient amount of proteins and the anaerobically digested effluent contained excess ammonia, with an approximately equivalent amount of alkalinity (Holliger, Fruteau de Laclos and Hack, 2017).

Lipids provide the highest biogas yield, but require a long retention time due to their slow biodegradability, whereas carbohydrates and proteins show faster conversion rates but lower gas yields (Esposito *et al.*, 2012)

The fermentation of FW substrates leads to high concentrations of nitrogen in the reaction medium derived from decomposition of protein. Nitrogen converted into ammonium ($NH^{+}4$) and free ammonia NH3, which is toxic for bacterial communities at elevated concentrations. Ammonia toxicity can cause serious problems of instability leading to dramatic damage of the process and even its failure (Liu *et al.*, 2018).

High ammonia attention in animal wastes is considered a factor of inhibition for anaerobic treatments .This problem is particularly serious when the digesters are fed with wastes rich in proteins because, during their fermentation, a significant increase of the ammonia concentration occurs (Esposito *et al.*, 2012).

Nitrogen is crucial for protein synthesis and primarily required as a nutrient by the microorganisms in AD .Nitrogenous compounds in the organic waste are usually proteins which are changed to ammonium by AD. In the form of ammonium, nitrogen contributes to the stabilization of the pH value in the bioreactor where the process is taking place.

Microorganisms assimilate ammonium for the production of new cell mass. A nutrient ratio of the elements C:N:P:S at 600:15:5:3 is considered sufficient for mechanization. Total biogas invention is unaffected by small nitrogen in ammonia while higher increases reduced the biogas assembly by 50% of the original rate. In the fluidized-bed anaerobic digester, the methane formation decreased at ammonium concentrations of greater than 6000 mgNH4–N/l. It was reported that methanogenic activity is decreased by 10% at ammonium concentrations of 1670–3720 mg NH4–N/l, while by 50% at 4090–5550 mg NH4–N/l, and completely zero at 5880–6000 mg NH4–N/l.The growth rate of acetogens is much higher than that of methanogens, and the AD process requires a balance between these two populations so that the rate of acid creation does not outpace methane configuration.

If organic acids accumulate because the methanogenic inhabitants is insufficient to convert the accessible organic acids into methane, the pH will drop, which may inhibit methanogens, ensuing in even less methane created (Chesshire, 2013).

2.5.7. C/N Ratio

The C/N ratio in the organic material plays a crucial role in AD. The unbalanced nutrients are regarded as an important factor limiting AD of organic wastes. Co-digestion of fish waste, abattoir wastewater and waste activated sludge with fruit and vegetable waste facilitates balancing of the C/N ratio. Their greatest advantage lies in the buffering of the organic loading rate, and anaerobic ammonia production from organic nitrogen, which reduce the limitations of fruit and vegetable waste digestion. The optimum C/N ratio for AD is in the range of 20/1–30/1(Esposito *et al.*, 2012). C/N ratio between 22 and 25 seemed to be best for AD of fruit and vegetable waste, whereas, The C/N ratio of 20–30 may provide sufficient nitrogen for the process.

In bacteria biomass the mass ratio of C: N: P:S is approx. 100:10:1:1. The ideal substrate C:N ratio is then 20-30:1 and C:P ratio 150-200:1. The C:N ratio higher than 30 causes slower microbes multiplication due to low protein formation and thus low energy and structural material metabolism of microorganisms.

On the other hand, the C:N ratio as low as 3:1 can result in successful digestion. However, when such low C:N ratios and nitrogen rich substrates are applied (that is often the case using animal farm waste) a possible ammonium inhibition must be considered. Ammonium although it represents an ideal form of nitrogen for microorganisms' cells growth, is toxic to mesophilic methanogenic microorganisms at concentrations over 3000 mgL-1 and pH over 7.4. With increasing pH the toxicity of ammonium increases (Zupančič and Grilc, 2007).

Recently, few Chinese researchers studied the AD of FW resulting in final total solids (TS) and volatile solid (VS), reaching the maximum of 52.07%, 63.46% and 90.92%, 95.85% respectively, study not only decreases the quantity of wasted food but also produce clean biogas (Batori and Nair, 2017)

2.6. General Process Description

The AD method has four main stages: Pre-treatment, waste digestion, gas recovery and residue handling. Pre- treatment of waste is very essential to obtain homogeneous feedstock. The pre-processing involves separation of non- digestible materials and shredding. (Mustafa, Calay and Román, 2016).

Batch processes

In the batch process all four steps of digestion as well as four stapes of healing procedure happen in one tank. Typically the reaction cycle of the anaerobic sequencing batch reactor (ASBR) is divided into four phases: load, digestion, settling and unload. A stirred reactor is filled with fresh substrate at once and left to degrade an aerobically without any interference until the end of the cycle phase. This leads to temporal variation in microbial population and biogas production. Therefore, batch processes require more precise measurement and monitoring equipment to function optimally (Zupančič and Grilc, 2007).

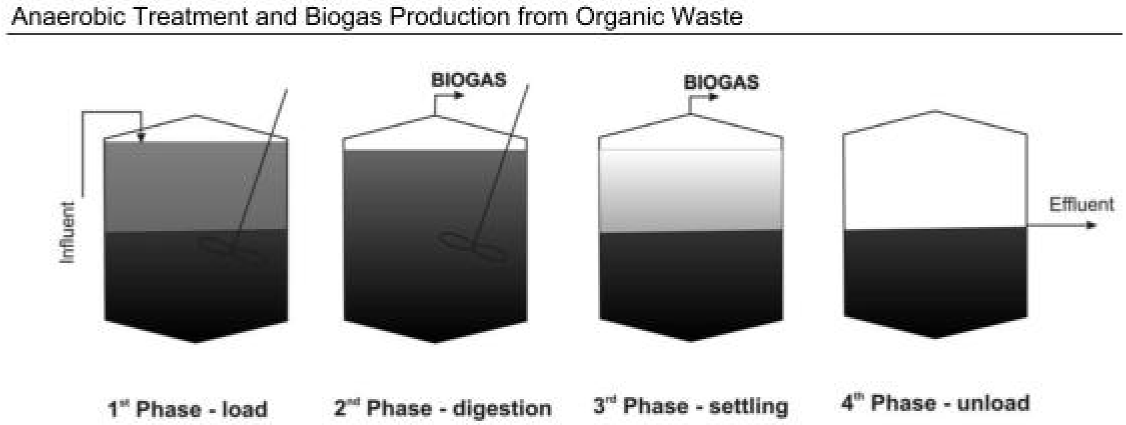

Figure 2: **Stage of biogas production**

2.7. Energy

Energy is a fundamental item for development and a powerful engine of social and economic change in any country (Akorede *et al.*, 2017).

Clean and renewable Energy recovery from waste represents an important way to reduce the amount of electrical energy that is produced from fossil fuels and reduce environmental impacts including global warming and acid rain. There are several technologies available to Conversion of biogas into power directly. Gas engine is one of the mostly used technologies for burning the biogas for power generation (Surroop and Mohee, 2012).

2.7.1. Biogas Conversion to Electricity

Is the chemical energy of the combustible gases is converted to mechanical energy in a controlled combustion system by a heat engine. This mechanical energy then activates a generator to produce electrical power.

Various technologies to generate electricity from biogas on a household level are available. Biogas can be converted directly into electricity by using a fuel cell. However this process requires a very clean gas and expensive fuel cells. Therefore this is not currently practical option. The conversion of biogas to electrical power by a generator set is much more practical. The most common heat engines used in biogas energy conversion are gas turbines and combustion engines. Combustion engines can be either internal combustion engine or external combustion engine. Combustion engines are more efficient and less expensive than small gas turbines. However, gas turbines may be more efficient when operating in Cogeneration or

Combined Heat and Power (CHP) describe the simultaneous generation of both electricity and useful heat (M A O Mydin *et al.*, 2014).

Heat engines (also thermal power plants) in general do not convert all of their thermal energy into electricity. In most cases, a bit more than half is lost as excess heat. By capturing the excess heat, CHP use heat that would be wasted in a conventional power plant, potentially reaching an efficiency of up to 89%, compared with 55% for the best conventional plants. This means that less fuel needs to be consumed to produce the same amount of useful energy. (Joshi *et al.*, 2017).

There are 3-phase electrical motor can be converted into generators. Biogas can be used as fuels in nearly all types of combustion engines, such as gas engines (Ottomotor), diesel engines, gas turbines and stirring motors etc(Joshi *et al.*, 2017)**.**

Benefit of biogas conversion to electric potential

It's used to supply electricity for vehicles fuels, lighting system, TV, radio, deck and music system, water heater, pressing iron, electric stove, grinding refrigeration, brick making or remote communications and energy intensive farming system(water pumper, dry).

Efficiencies of biogas conversion to electric potential

The calorific value of biogas is about 6kwh/m^3 which corresponds to about half litters of diesel oil and can be utilized directly as a heat sources or to produce electricity. In all case the biogas must be dehumidified and purified before combustion otherwise it can damage the engine(Joshi *et al.*, 2017).The biogas consisted of 60% CH_4 volume is represent significantly amount of energy. The energy content of CH_4 is taken to 37.5MJ/kg bio waste and the efficiencies of the gas engine is 33%(7.54MW)power (Akorede *et al.*, 2017).

According to Mkiramweni, Msaki and Mshoro, (2005)description of the three classes of system modern rural area power requirement

Table 2: electric potential needs

Classification of electric needs	List of component in need of electricity	Power requirement(KW)
House hold	Cooking	3
	lighting	1
	radio, TV, iron, Refrigerators , water heater	2
farming	Intensive farming systems	10
	Commercial enterprising systems	15
Business	Commercial Supply about 5 to 10 houses	30-60
	Workshop e.g. Welding, Machine shop, etc	30-60

Combustion Engine

a. External combustion engine:

Stirring Motors: biogas is combusted externally, which in turn heats the stirring motor through a heat exchanger. The resulting work is used to generate electricity. its advantage is tolerant of fuel composition and quality.Its disadvantage, are expensive and characterized by low efficiency.

b. Internal combustion engine:

Diesel Engines: operate on biogas only in dual fuel mode. To facilitate the ignition of the biogas, a small amount of ignition gas is injected together with the biogas.

Gas Motors with spark ignition (Otto system) can operate on biogas alone. In practice, a small amount of petrol (gasoline) is often used to start the engine. This technology is used for very small generator sets (~ 0.5-10 kW) as well as for large power plants. These engines have advantages as they do not need additional fossil fuels that would lead to lower feed-in tariffs according to the Renewable Energy Law (EEG).

Gas Turbines are occasionally used as biogas engines. Small biogas turbines with power outputs of 30-75 kW are available in the market. They are expensive and due to their spinning at very high speeds and the high operating temperatures, the design and manufacturing of gas turbines is a challenging issue from both the engineering and material point of view. requires specific skills (Muthu *et al.*, 2017).

The biogas consisted of 60% of methane by volume which represented a significant amount of energy. The energy content of methane was taken to be 37.5 MJ/kg and the efficiency of the gas engine was taken as 33% (Surroop and Mohee, 2012).

2.8. Solid residue

The solid residue produced from hydrolysis of food waste is a safe biofertilizers. However, the solid residue generated after anaerobic co-digestion of activated sludge and liquor produced from the hydrolysis of food waste had a quality. ultra-hydrolysis of 1 kg dry food waste, 0.652 kg of biofertilizers was obtained(Ma, Yin and Liu, 2017).

The residual products for digestion can be used as low grade fertilizers and have also been used for livestock bedding (Surroop and Mohee, 2012).

CHAPTER THREE

3. OBJECTIVES OF THE STUDY

3.1. General objectives

- To investigate recoverable potential of electric energy from biogas produced anaerobic digestion of food waste, the case of Jimma University.

3.2. Specific objectives

- To estimate generation rate (mass) of post consumer FW per a day, week and a year from Jimma university.
- To estimate the amount of biogas produced from food waste
- To estimate the amount of electricity from biogas generated from combined food waste collected from selected sources of Jimma University.

CHAPTER FOUR

4. METHODS AND MATERIALS

4.1. Description of the study Area

The study was conducted at Environmental Science and Technology Laboratory, and Institute of Technology laboratory, of Jimma University, Ethiopia, which is located 350 km south-west of Addis Ababa (capital of Ethiopia) and Addis Ababa University. Its geographical coordinates are approximately 7° 41′ N latitude and 36° 50′ E longitude. Jimma is found in an area of average altitude of about 1,780 m above sea level. The mean annual maximum temperature is 30 °C, and the mean annual minimum temperature is 14 °C (FDRE, 1998). Data collection and experimental analysis was conducted from March to Jun 2018 during rainy seasons.

Chemical and Materials: The materials that were used to construct the bio-digester are FW, tap Water, Na_2HCO_3, NaOH, gum(super glue), and, also, the apparatus that were used for the experimentation are Edibon digester machine, and water bath, local mortar, pH meter, Containers, Hand Gloves, Thermometer, Stirrer, Weighing balance, gas collection unit(bag),Sevier, were utilized during the fabrication the digester.

4.2. Experimental design and set-up

Mesophilic temperature condition at (35±2℃) and batch digestion reactor system experiments was conducted. According to Khalid *et al.*, (2011)batch reactors are the simplest, filled with the feedstock and left for a period that can be considered to be the hydraulic retention time, after which they are emptied. Anaerobic batch reactors are useful because they can perform quick digestion with simple and inexpensive equipment, and also are helpful in assessing the rate of digestion easily. On the other hand, batch reactors have some limitations such as high fluctuations in gas production as well as gas quality, biogas losses during emptying the bioreactors and restricted bioreactor heights.

Anaerobic digesters was generally constructed in lab scale experiments where biogas is produced out of the degradation of organic matter in 5L Edibon digester machine with appropriate working volume. One plastic tube was taken through the stopper which acts as an outlet for the gas and closed airtight .2nd shift was taken for the experiment with replications. The lids of all digester are sealed strongly using super glue and gum in order to control the entry of oxygen and loss of biogas. After measuring the initial pH values of all the digesters, their pH values were arranged between 7.2 and 7.59 by adding Na_2HCO_3 buffer solution to lift the pH value to optimum value. According to reported by Ziauddin and Rajesh, (2015) NaOH & $NaHCO_3$ added to slurry for the purpose of increase/adjust pH value at optimum range. High moisture (wet state) NaOH pretreatment technique was used to pretreated corn stove, which is believed to be a cost-effective and efficient approach for AD process before feed in to reactors(Liu *et al.*, 2018).

The amount of air initially present in the empty bottle was sacked by machine outlet after feeding and sealing the digester substrate to maintain AD. The natural temperatures of all the digesters were controlled at 35 ± 2^0C using water bath to control maximum temperature fluctuation.The daily gas production was recorded for all stocks until the gas production stops.

By the anaerobic fermentation of the amount of mass of FW residues has been produce meter cubic of biogas daily and calculate kWh of electric energy was derived by its treatment. Therefore it is reasonable that the annual recovered electricity was calculated in the form of MW or kW was recorded.

4.3. Sample collection

The daily production of FW in Jimma university hospital and students cafeteria from the leftovers in dishes was collected, measured and recorded on eight consecutive days by manually collecting, during the winter of 2018.All the samples was collected before having contact with any other type of waste to avoid contamination. Jimma University has a capacity of serving 14,500 cafeteria users' students and 1080 bed dependents patient daily.

FW generation rate from Jimma University student cafeteria and specialized hospital was estimated.

Samples was collected by shovel and placed into a seven-gallon bucket. All the FW sample was shipped to the laboratory and, the two collections was mixed in equal proportions and placed the waste in the sun and dry for five days.

4.4. Parameters to be measured

4.4.1. Total Solids (TS)

Total Solids (TS %) - It is the amount of solid present in the sample after the water present in it is evaporated. The sample, should taken and poured in foil plate and dried to a constant weight at about 105^0C in oven for 24 hours according to Ziauddin and Rajesh, (2015,Sluiter et a.l, 2008) 800g of freshly collected and dried in the sun FW samples was weighed using electrical balance, and placed inside an electric hot air-oven maintained at 105°C using a crucible. The crucible was allowed to stay in the oven for 24 hours, then taken out, cooled in a desiccators and weighed. Then the percentage of the TS was calculated as:

$$\%TS = \frac{Mdry}{Mfresh} \text{ x } 100$$

Where: M_{fresh} = fresh mass and

M_{dry} = dry mass after heating at 105°C for 24 hrs using a hot air oven

4.4.2. Volatile Solids (VS)

According to Macias-Corral et al., (2008)volatile content of the raw material was determined by drying the samples at 550 ^{0}c furnace for three hours. The following formula is employed to calculate the percentage of volatile solids content of the TS.

$$\%VS = \frac{Mdry\_Mash}{Mdry} \text{ x } 100$$

Where: M dry = dry mass and

M ash =remaining mass after ignition at 550 ^{0}c furnace for 3hrs.

4.4.3. Moisture content (MC)

Moisture content is the amount of water evaporated from the sample. To determine the percentage of moisture content (MC) in the samples, 500 g of fresh substrate was dried in an oven at 105 °C for 24 hours and reweighed. Then the moisture content in percent was determined by using the following formula based on American Society of Testing and Materials (ASTM, 2001).

MC=fresh sample-Dried sample

$$\%MC = \frac{Wi-Wf}{Wf} x100$$

Where; MC = moisture content

Wi = initial weight of sample in grams,

Wf = weight of sample after drying at 105 °C in grams.

4.4.4. Organic carbon (OC)

The total organic carbon content is obtained from percentage of volatile solids data using an empirical equation as reported by Barrington et al., (2002).

Organic Content – Organic dry matter weigh the sample and weigh remaining ashes Organic content = {Mass of TS - Mass of ashes}/Mass of TS (Ziauddin and Rajesh, 2015).

$\% OC = \frac{\%VS}{1.8}$ Where, VS-Volatile solid

OC- Organic carbon

4.4.5. Total nitrogen (crude protein)

The Kjeldahl procedure was employed to analyze the total nitrogen content of the feed stocks (Gerardi, 2003)0.3g dried samples (food) were placed on a digestion tube with 5mL of concentrated sulfuric acid. 7 g of each potassium sulfate and copper are then added. The digestion tube was placed into a digestion block where it was heated at 370 °C. Sodium hydroxide was then added to change ammonium ion to ammonia in the digester, and the nitrogen was separated by distilling the ammonia and collecting the distillate in 0.1 N sulfuric acid solutions. Determination of the amount of nitrogen on the condensate flask was done by titration of the ammonia with a standard solution of 0.1N sodium hydroxide in the presence of methyl red indicator in 0.1 N sulfuric acid solutions. Finally, the amount of nitrogen present was calculated using the formula:

$$\%N = \frac{[1.4007\ x\ (Va-Vb)\ x\ N]}{W}$$

Va: volume of acid used for sample titration

Vb : volume of acid used for the blank

N: Normality of acid

W: sample weight in grams

1.4007: conversion factor mill equivalent weight of nitrogen and N percent

%CP = %N × F

Where; CP= Crude Protein

F = conversion factor (F =6.25 for all forages)

Finally, the ratio of carbon to nitrogen was calculated as:

$$Carbon\ to\ nitrogen\ ratio = \frac{\%carbon}{\%nitrogen}$$

4.5. Feed Stock preparation

The Mono-digestion experiments were conducted in bench mode in 5L edibon machine digester with 1 substrates prepared in two different proportions of FW labeled and moisture content as S1(stocks) and S2(stocks). As suggested by Rai (2004), substrates were mixed with appropriate amount of tab water and inoculums to achieve the recommended (8% w/w) total solids content in the fermentation slurry. The total amount of liquid (tab water and activated sludge) needed to be added to the digester was then determined by the following formula.

$$Y = \frac{mTS - 8\%X}{8\%}$$

Where,

mTS = mass of total solids

X = mass of fresh substrate

Y = mass of fluid (tab water and sludge) to be added to get 8% total solids in the digester

Then, by fixing the amount of inoculums (150 ml) that is added finally to facilitate digestion, the amount of tab water that had be added was then determined using the following formula;

Z= Y-100

Where;

Z = amount of tab water

Y = total amount of liquid (tab water and sludge)

Inoculums

The inoculums was taken from Jimma town Degitu hotel AD and stored for three days at room temperature.

The inoculums should be stored on average for 2–3 days at room temperature in a completely filled and closed plastic container in the period from sampling to setting in the digester tests during which TS, VS, and eventually other parameters (pH, NH4 and VFA concentration) are determined according to Holliger, Fruteau de Laclos and Hack,(2017).

Higher amounts of inoculums resulted in higher concentrations of VFA, causing a reduction of the biogas yield. The maximum specific biogas production was obtained using the minimum amount of inoculums (10-20%) for 24%MSW total weight (Al-Zuahiri *et al.*, 2015).

After a two-day gravity sedimentation period, the supernatant was discarded, and the remainder was screened by a 2mm sieve to remove impurities(large particles/grit) and prevent clogging problems prior to be used according to Li *et al.*, (2018).

Treatments were randomly arranged in the lab and done in replicates. Initial pH values were also maintained within the pH range for optimal biogas production (Yadvika et al., 2004).

4.5.1. Experimental procedures

According to Awasif, Maskhoot and Saadi, (2016) protocols(experimental procedures)were used for the production of biogas from various waste material sources. Dilution with water with 1:1 ratio and sampling for further analysis and feeding inside the digester.

In this study the steps should be followed.

1. FW was dried for five days in sun light then, crushed by local mortar and sieved by using 2mm Sever.
2. Fine slurry was prepared by mixing crushed FW to 2mm size with tap water and inoculums in the ratio of 1.5:2.5:1 (30:50:20% and1:3:1 (20:60:20%).to obtain a homogenous mixture.
3. A fresh sample was taken from the slurry for physicochemical analysis, such as the measure of pH of the sample before entering the digester.
4. The reactor was prepared separately and labeled as stocks (S)1 and stocks(s)2 made in the table-2 proportion.

5. Finally insert the slurry into the digester with the suitable temperature and PH.

Fabrication of the suitable design of biodigesters of the two identical digesters with a liquid volume of 5 liter is shown in Fig.3. The double glass shell of the digester is used for heating and gives the possibility to observe mixing and liquid level. Mixing is realized by a central stirring system with two mixing elements. At the bottom a ball valve allows to discharge the digester or to take samples.

Each Stocks has a total mass of dried FW was 225g and 150g respectively.

second term dry mass sample obtained after drying in an oven at 105 °C for 24hrs for this study taking the container volume in to consideration. The proportion of mixed waste was modified

based on the study conducted by Iyagba et al., (2009) in Nigeria and Adebayo et al., (2014) in Germany. Accordingly;

Table 3:FW stock solution ratio in AD

Sample type	inoculums	water	FW	Total slurry(ml)	Ratio
Reactor 1	20%=150ml	50%=375ml	30%=225g	750ml	1:2.5:1.5
Reactor 2	20%=150ml	60%=450ml	20%=150g	750ml	1:3:1

Figure 3: Stock solution pH adjustment and feed to the digester

.

Methods used: The edbon digester machine having capacity 5liters was used as bio-digester. Concentration & combination of wastes were used.Like total solid, volatile solid, pH, Temperature, Nitrogen, Carbon, was measured while continuous study was done to check the gas production

4.6. Detection and measurement of biogas produced

Presence of biogas produced or not was detected by observing the characters of water displacement from the cylinder.

Water displacement method was used for the measuring amount of total biogas produced by directly reading amount of water account to ml displaced from the cylinder by biogas produced(Yetilmezsoy et al., 2008).

4.7. Composition of biogas

Biogas produced was evaluate as it contains Methane, Carbon dioxide, hydrogen sulfide, oxygen and other substances by using biogas analyzer machine. Electricity generation from biogas varies depending on the methane content of the biogas. Using the gas for direct combustion in house hold stoves or gas lamps is common, but producing electricity from biogas is still relatively rare in most developing countries. Power generation is the main purpose of biogas plant; conversion of biogas to electricity has become standard technology. This paper was address the biogas production process and pure methane separation from biogas in general at lab scale but the findings(unique) present here are mainly based on electricity generation from biogas at lab scale.

The potential recoverable electric energy was estimated as;

$$\Delta Q = M(-\Delta U) * A * B$$

Where: ΔQ, is the potentially recoverable electric energy (kWh), M is the total methane production (m^3), -ΔU is the combustion energy of methane gas at a constant volume equal to 40 MJ/m^3 ,A is the conversion coefficient of methane chemical energy to electricity through combustion, equal to 35%, and B is the conversion coefficient of energy (MJ) to electric energy (kWh),equal to 0.28(Ma, Yin and Liu, 2017)

CHAPTER FIVE

5. RESULT AND DISCUSSION

The frequencies and percentage item of the FW generated was shown in table.4

Table 4:FW generated composition frequencies and percentage.

Types of food/week	rice	Firfer	kinche	vegetable	meat	Meat with potato	lentil	pea	Total
No of consumption/ week	3	2	2	1	2	2	3	6	21
Percentage (%)	14.3	9.52	9.52	4.8	9.5	9.5	14.3	28.6	100

When frequency of food type eaten by student per a week in Jimma University were converted into percentage form was described in fig.4

.

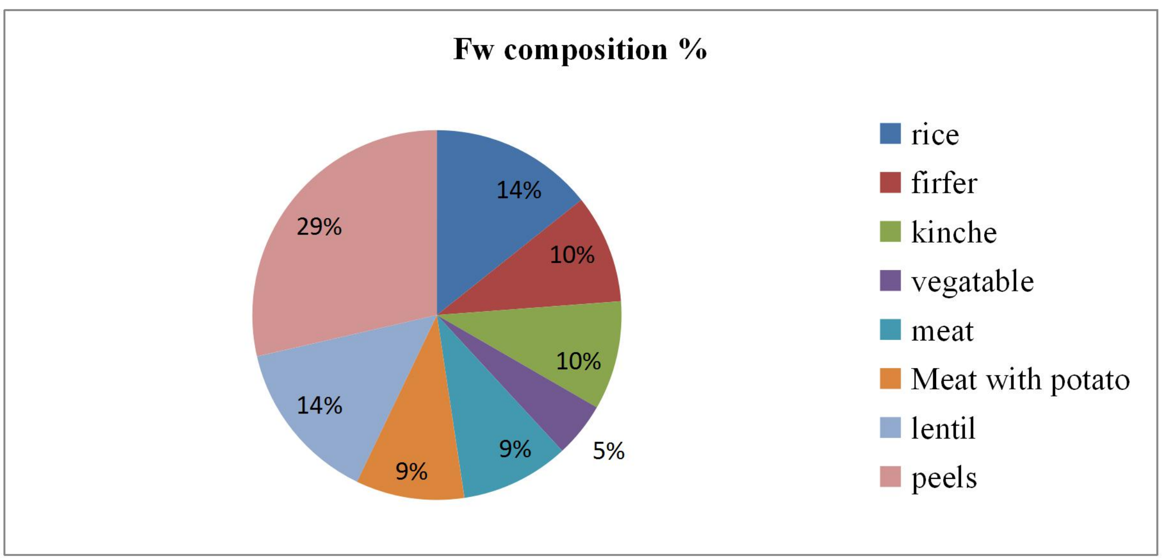

Figure 4:Jimma University student's cafeteria food item percentage

General FW generation rate from Jimma University student cafeteria and Jimma university specialized hospital were indicated in table- 5

Table 5: General average of FW generation rate from Jimma University.

s/no	FW source	FW/p/d(Kg)	Total FW /d(Kg)	FW/p/w (Kg)	Total FW /week(Kg)	FW/p/annum(Kg)	Total FW/annum(Kg)
1	Sheretan(no-2)	0.15	333.50	1.16	2668	52.93	121727.70
2	Zegeye (no-3)	0.13	756	1.01	6048	45.99	275940
3	JU specialized hospital	0.11	96	0.85	768	38.69	38070.96
4	JU agricultural college	0.14	210.50	1.13	1684	51.10	76650
5	JU institute of technology	0.14	655.75	1.12	5246	51.10	240170
	total	0.66	2,035.63	5.21	16,285	263.96	752558.46 (752.56tone)

Total average of FW generation rate from Jimma university was calculated according to reported by Guidelines For Solid Waste Management Assessment (Baseline Survey) In Secondary Cities And Small Towns In Asia And The Pacific, (2010),to determine the total quantity of waste generated in the city, multiply the present population of the city by the total per capital waste generation rate.sot that the total average of FW generated rate per person/day, week and year while total per annum based on this formula.

Total average of FW generated/person/day was 0.657Kg

Total average of FW generated /day was 2,035.630 Kg

Total average of FW generated/person/week was 5.210 Kg

Total average of FW generated /week was 16,285 Kg

Total average of FW generated/person /annum was 263.960 Kg

Total average of FW generated /annum was 752558.46kg (752.56tone

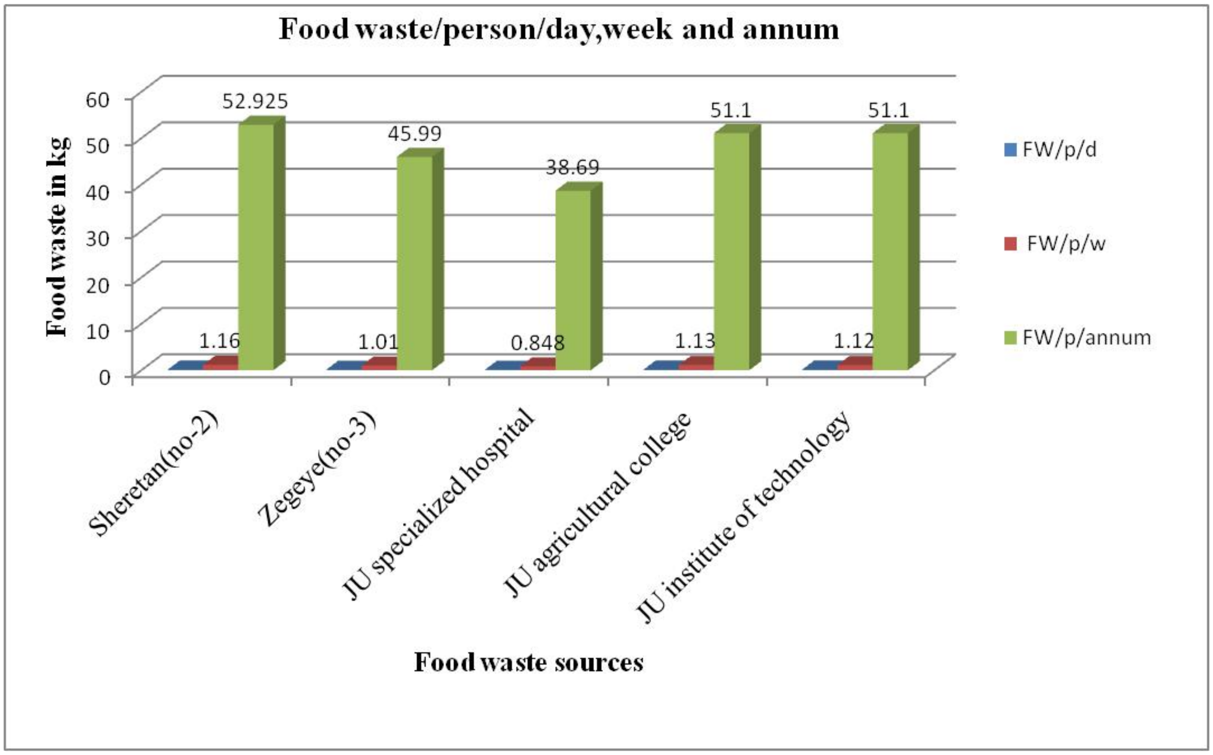

Figure 5: Generation rate of FW per person per a day and per week

As it expressed in fig 5 large amount of FW or 0.145kg/person/day and 1.16kg/person/week was generated from Sheraton (student cafeteria no.2) than the other FW sources. While Jimma university specialized hospital was generate list amount of FW (0.84kg/p/day and 0.106kg/p/week) when compared to the other.

As it observed from data collection which indicated in fig.5 the total average of FW generation/person/annum was abundant at Sheraton(student cafeteria no.2) which can generate 52.925kg/person/annum and the minimum FW generation rate per person per annum account to 38.69kg was found from Jimma University specialized hospital.

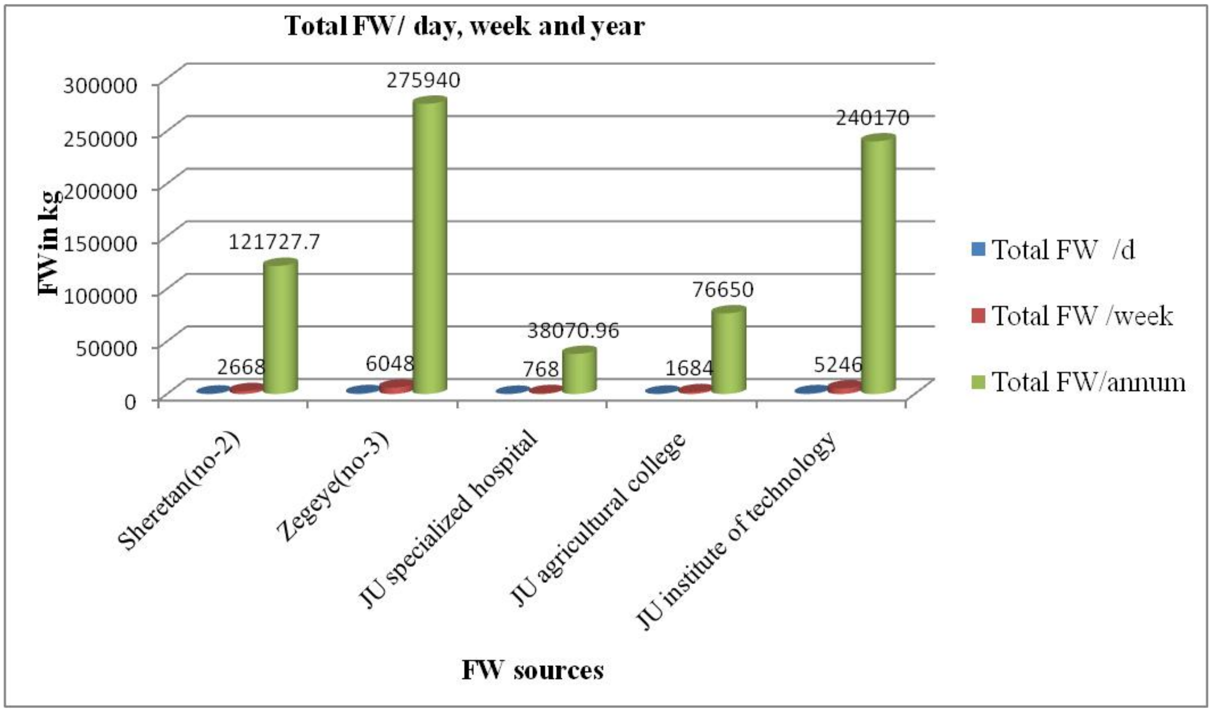

Figure 6: Total FW/day and week and annum

This graph is expressed the amount of total FW generated/day and week. Based on that the maximum amount of FW account to756kg/day and 6048kg/week were generated from Jimma university zageye (student cafeteria no.3) while small amount of FW which account to 96kg/day and 768/week was generate from Jimma University specialized hospital than the others sources. The total FW generation rate/annum was also higher in zegeye (student cafeteria no.3) which account to 275940kg/annum and also the small amount of total FW generation rate/annum which account to 38070.96kg/annum was from Jimma University specialized hospital.

5.1. Physicochemical properties of the substrate used in FW digestion

The physicochemical characteristics of FW mixed in different proportion of water were determined before and after; AD and the result are discussed blow.

5.1.1. Total solids

The initials of total solids (TS%) content of the feed stocks was 211.33g for stock 1 and 140.88g for stock 2,with the highest value for stock1 and lowest value for stock 2(table 6).

Table 6: FW physicochemical characterization.

parameters	Reactor 1		Reactor 2	
	Initial%	Final%	Initial%	final%
MC	8.07	76.5	6.92	83
TS	28.00	24.00	18.00	16.00
Weigh of ash	15.80	11.20	15.80	10.40
VS	83.10	65.70	75	61
OC	24.13	11.95	16.10	8.35

The total solids which were held at 28% and 18% showed a decrease after the retention period of 23 days which were found to be only 24% and 16% in reactor 1 and reactor 2 respectively. In this study the total solid of substrate was present in the recommended range of AD. So that it can be supported, According to Khalid *et al.*, (2011) reported that wet bioreactors have total solids of 16% or less, while dry bioreactors contain 22–40% total solids, with the intermediate rating termed ‘semi dry.

Low-solids content of organic waste (<15%Total Solids) sometimes also called “wet digestion”;while High-solids content (25-30 % TS) also known as “dry digestion “organic waste according to suggested by Arsova, (2010).

The process was unstable below a total solids level of 7% (of manure). So that the higher solid content in feed stocks decreases the cumulative volume of biogas production, due to slurries of higher TS concentrations were more acidic than that of lower TS concentrations, as reported by Somashekar, *et al.*,(2014).

The initial percentage of total solid content of the feed stocks did not agree the recommended range of 22–40% substrates were mixed with appropriate amount of tap water and inoculums to achieve the recommended range 16–40% total solid content in the fermentation slurry for better biogas production.

The percentage of total solids and organic carbons of those two fed stocks before AD was illustrated in table-5 above were desirable for AD, due to present in the range recommended by different references.

5.1.2. Volatile solids (vs %)

Volatile solids are the solids that are lost or ignition of the dry solids at 550°C,reported by (Somashekar, Verma and Naik, 2014). As observed from experimental analysis of this study VS reduction was occurred in the slurry during the digestion. The VS fed on an average basis into the digester were found to be 83.1% and 75% of reactor 1 and reactor 2 respectively. The VS found after the digestion process was found to be 65.7% and 61%.Thus there was about 17.4% and 14% decrease in volatile solids.

The VS content of both the treatment in this study was in the range of 75-83.1%(tabl-4),this VS was in agreement with the recommended value for biogas production (70-95%) reported by (Somashekar, Verma and Naik, 2014). VS are responsible for biogas production since FW contains 75-83% of volatile solids thus it has a great potential of biogas production and can be used easily and potentially as a raw material for biogas production. Potential of gas production can usually be estimated from the VS loading of the digester and the percentage of VS reduction through digestion.

Significance differences were observed between %VS of both reactor 1 and 2 of AD. After AD, VS of all reactor type were significantly decreased, but more decrease was observed in reactor 1 than in other reactor. This suggests that less moisture content desirable for microbial activities in organic waste degradation, while mixing and optimum C/N ratio can enhance degradation and biogas production. Removal of VS after AD its convention to biogas. VS distraction was good parameters for evaluating the efficiency of AD.

5.1.3. Moisture content

Experiment result showed that there was a significant difference in moisture values with in reactor 1 and reactor 2 AD. The mean moisture content of partially dried substrate before AD was 8.07, and 6.92. The initial moisture content partially dried FW did not agree with the recommended range of AD, but after it was mixed with a ratio amount of tap water and inoculums the AD process was entered to the feasible moisture content for AD. After AD the moisture content of reactor1 and reactor 2 were 76.5% and 83%. (tabe2) these results showed that the moisture content (water) after AD was increased than before AD. This is due to added tap water to adjust moisture content in the digester and inoculums for microbial requirement. It has been reported that the highest methane production rates occur at 60–80% of humidity, (Khalid *et al.*, 2011).

The biodegradable fraction of MSW contains anywhere from 15%-70% water but FW is characterized by high percentages of moisture (> 70%) and Volatile Solids (> 95%) and has a very high biodegradability (Arsova, 2010).

Some important characteristics of FWs that have been reported include a moisture content of 74–90%, volatile solids to total solids ratio of 0.8–0.97, and carbon to nitrogen ratio of 14.7–36.4 according to suggested by (Pham *et al.*, 2015)

5.1.4. Organic carbon (OC)

As the experimental analysis indicate in this study the Percent carbon content in the feedstock was found to be 24.13% and 16.1% before AD in the FW slurry, and 11.95 and 8.35 after AD**.** The present OC of Reactor 1 was higher than Reacto2 slurry (table 5).The results also revealed that there was a difference in %OC in ratios between before and after AD. Compare of initial and final %C showed that %C significantly decreased in all reactor types. OC can be removed in anaerobic digesters either by being converted to cellular material for growth and reproduction of bacteria or biogas production. Therefore the decrease of Carbon reflects the degradation process during AD. More degradation of OC was observed in high moisture contents of Reactor 2 due to low loading rate substrate. These suggest that the microbial abundances can enhances degradation and biogas production.

As FW was used, it contains enough carbohydrates and less cellulose and lignin content, thus the removal of carbon content was fast. The reduction of Carbon by anaerobic processes was probably limited to the production of organic acids, H_2 and CO_2 by facultative bacteria as suggested by, (Somashekar, Verma and Naik, 2014).

5. 1.5.Carbon to nitrogen ratio

Too much increase or decreases in the carbon/ nitrogen ratio affect biogas production. The C/N ratio in the organic material plays a crucial role in AD. The unbalanced nutrients are regarded as an important factor limiting AD of organic wastes(Khalid *et al.*, 2011).

As a result methane yield and its production rates were highly influenced by the balance of carbon and nitrogen in the feeding materials.The C/N ratio of the substrate before AD was illustrated in table 6 blow.

Table 7: **The carbon and nitrogen ratio in FW before AD.**

Treatment	C:content	N:content	C:N ratio
Reactor 1	54	2.19	24.68
Reactor 2	36	1.45	24.83

The C:N ratio content of all reactors measured was between 24-25 ratio(table 7)Which agrees with the recommended value of (20:1 to 30:1).The optimum C/N ratio for AD is in the range of 20/1–30/1, reported by Esposito *et al.*, (2012). This indicates that FW could serve as a substrate for biogas production even without mixing it with another substrate (cow dung, khat etc). Due to the ratio was still in the range of 21:1 to 30:1.therefore in FW substrate the ratio of C:N is good performances for bacterial growth and reproduction, which can made feasible AD. So that post consumer of mixture FW mono digestion alone could be used for AD to produces biogas.

According to Zupančič and Grilc, (2007) reported that the ideal substrate C:N ratio is then 20-30:1. The C: N ratio higher than 30 cause slower microorganisms multiplication due to low protein formation and thus low energy and structural material metabolism of microorganisms. The C: N ratio as low as 3:1 can result in successful digestion. However, when such low C: N ratios and nitrogen rich substrates are applied (that is often the case using animal farm waste) a possible ammonium inhibition must be considered. Ammonium although it represents an ideal form of nitrogen for microorganisms' cells growth, is toxic to mesophilic methanogenic microorganisms at concentrations over 3000 mgL-1 and pH over 8. With increasing pH the toxicity of ammonium increases.

5.1.6. Daily biogas production versus temperature and time in reactor 1

The many lower temperature and the temperature fluctuations were adversely affect the performance of biogas production in AD. In general, high temperatures produced lower biogas due to the production of volatile gases such as ammonia which suppresses methanogenic activities (Khalid *et al.*, 2011).The day temperatures of the mesophilic digestion was measured three times a day: at morning(8:00AM),noon(2:00PM) and dusk(8:00PM) and the average result was shown in table 8.

Figure 7: Biogas collected from edibon AD machine, in to IV bag.

The volume of produced biogas was collected daily by using a water displacement system. Daily biogas production (ml) from the combination of inoculums, tap water and FW in the ratio 1:2.5:1.5 was adjusted in set1 (1st reactor) was identified based on temperature variety.

Table 8: Daily mesophilic temperature measured and biogas produced in reactor1.

Day	1st round		2nd round		average	
	Tem(°c)	Biogas(ml)	Tem(°c)	Biogas(ml)	Temp(°c)	Biogas(ml)
1	33	99	34	96	33.5	97.5
3	35	250	35	246	35	248
5	35	300	35.5	333	35.5	316.5
7	25	100	33	300	29	200
9	35	188	26	252	30.5	220
11	36	386	36.5	311	36.5	348.5
13	35	370	36	262	35.5	316
15	37	378	34	200	35.5	288.5
17	36	310	35	123	35.5	216.5
19	36	283	25	90	28.5	186.5
21	35	25	33	25	34	25
23	37	17	35	19	35	18
Average	33.5833	244.363636	32.9	203.454545	33.2433	223.909091

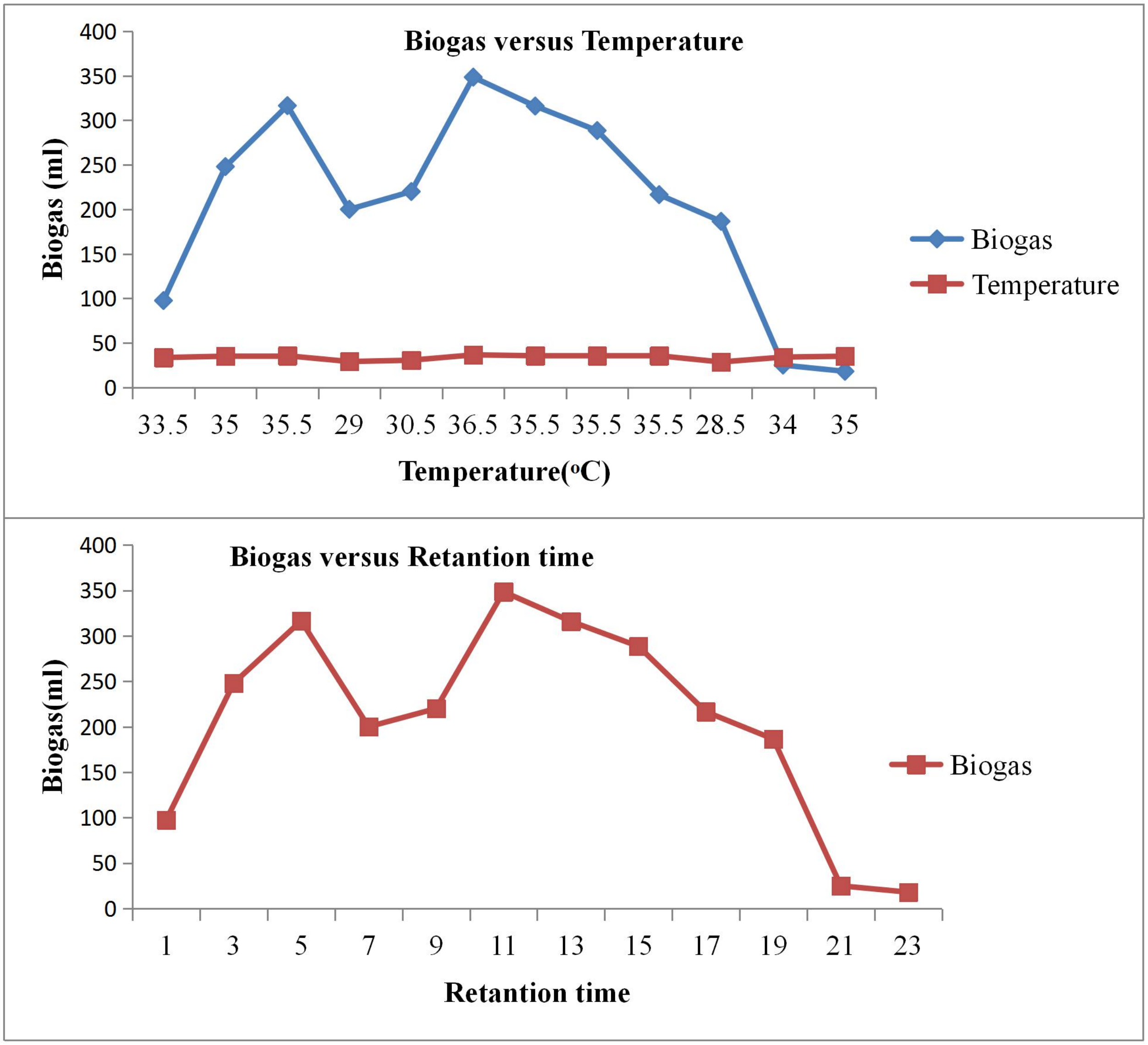

Figure 8: Effect of temperature and retention time on biogas production in reactor1

From fig 8: showed that large amount of biogas was produced at day 11 which account to 348.5 due to its presence in the preferable mesophilic temperature rates that available for micro bacterial activities in AD. While lower amount of biogas which account to 18 ml was produced at 23 day, due to FW nutrient content was decreased at the end of AD that is related with retention time.

Temperature is an important factor in the biogas production. Most of the acidic forming microorganisms grow under mesophilic conditions; however for methanogens, higher temperature is favorable**.**

AD can operate in a wide range of temperature. Generally there are three widely known and established temperature ranges of operation:

Temperature fluctuations in thermophilic range should be no more than ±1°C. In mesophilic range the microorganisms are less sensitive; therefore fluctuations of ±3°C can be tolerated. Psychrophilic (15-20°C), Mesophilic digesters have an operating temperature in the range of 25- 40 °C and thermophilic digesters have operating temperature in the range of 50- 65 °C. But Mesophilic AD processes function at about 37°C Anaerobic (Arsova, 2010).

Many Lower temperatures during the process are known to decrease microbial growth, substrate utilization rates, and biogas production. Moreover, lower temperatures may also result in an overtiredness of cell energy, a leakage of intracellular substances or complete hydrolysis. The operation in the mesophilic range is more stable and requires a smaller energy cost. The best operational temperature was 35^0C with an 18 day digestion period while a little fluctuation in temperature from 35 ^{0}C to 30 ^{0}C caused a reduction in the rate of biogas production. Overall, microorganisms exhibit optimal growth and metabolic rates within well defined of temperatures range between 35– 37^0C is considered suitable for the production of methane (Khalid *et al.*, 2011). In this study based on that the minimum and maximum day time average temperature of the study mesophilic were 28 and 37^oC

2. Daily biogas production versus temperature and time in Reactor2

Daily biogas production in (ml), identification based on temperature variability from the combination of inoculums, water and FW in the ratio 1:3:1in set 2(reactor 2).

Table 9: Daily mesophilic temperature measured and biogas produced in reactor2

Day	1st round		2nd round		Average	
	Tem(°c)	Biogas(ml)	Tem(°c)	Biogas(ml)	Temp(°c)	Biogas(ml)
1	32	102	35	90	33.50	96
3	34	246	35	250	34.50	248
`5	35	333	35	313	35	323
7	25	300	35	296	30	298
9	33	252	24	231	28.50	241.50
11	35	311	34	300	34.50	305.50

13	34	262	35	265	28	263.50
15	25	200	34	205	28	202.50
17	35	125	25	125	27.50	125
19	35	90	24	85	28.50	87.50
21	34	25	35	32	30	28.50
23	35	16	35	19	35	17.50
Average	31.66	204.18	32	185.58	31.83	194.88

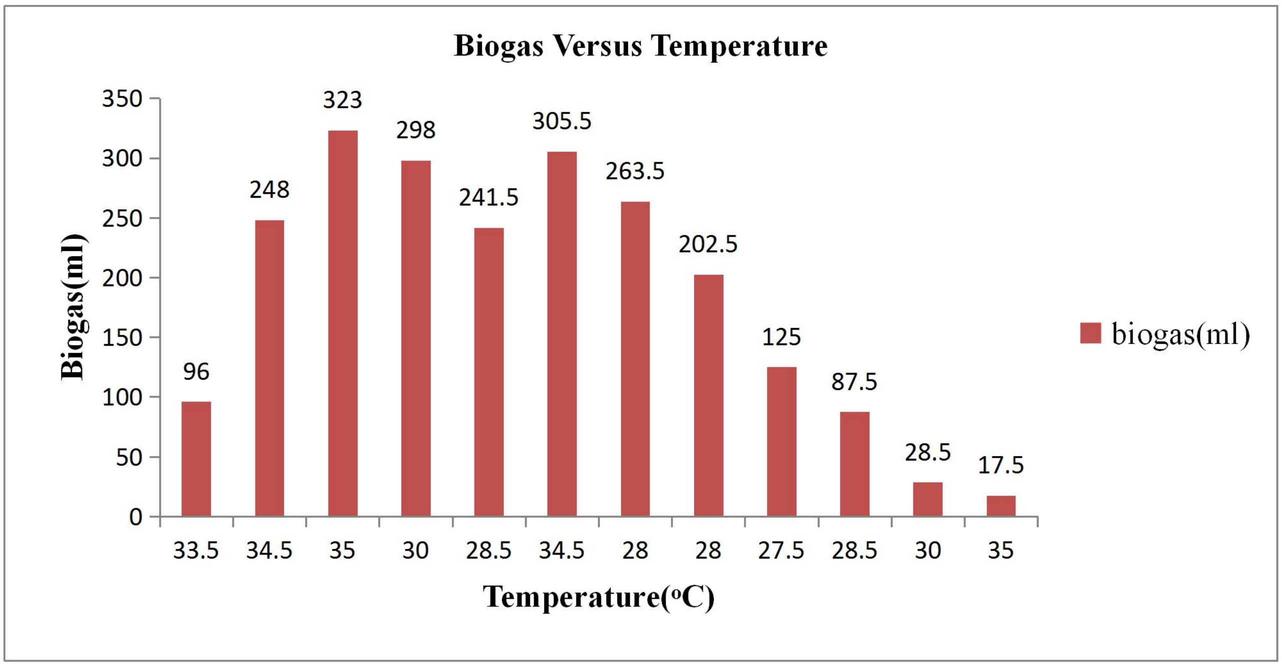

Figure 9:Effect of temperature on biogas production in Reactor 2.

From the above experimental analysis the largest biogas was produced at 35°C due to the temperature is recommended to optimum range of mesophilic temperatures. And the least biogas was yield at 35°c due to FW nutrient was inhibited and AD was almost completed.

5.1.7. Daily biogas yield versus pH measured

Daily biogas production in (ml) identification based on pH variability from the combination of inoculums, water and FW in the ratio 1:2.5:1.5 in set 1(reactor1) result was indicated in table.9 blow.

Table 10: **Daily biogas yield and pH measurement.**

Day	1st round		2ndround		Average	
	PH	Biogas(ml)	PH	Biogas(ml)	PH	Biogas(ml)
1	7.3	99	7.2	95	7.25	97.5
3	6	250	6.2	255	6.1	248
5	6.5	300	6.5	387	6.5	316.5
7	6.5	100	7	380	7.25	200
9	7.85	188	7.5	252	7.7	220
11	7.25	386	7.5	320	7.5	348.5
13	7.3	370	7.65	370	7.5	316
15	7.5	377	7.8	365	7.7	288.5
17	6.75	310	6.8	300	6.8	216.5
19	7.5	283	6.35	100	6.55	186.5
21	6.5	25	6.7	25	6.6	25
23	7.4	17	7.6	19	7.5	18
Average	6.86583333	244.363636	6.91666667	258.545455	6.91666667	223.909091

Experimental analysis of reactor 1 showed that the pH of day 2 was not between the optimum ranges of pH which available for biogas production. The most favorable range of pH to attain maximal biogas yield in AD is 6.5–7.5 (Khalid *et al.*, 2011). In AD systems, methane fermentation takes place within the pH 6.5 to 8.5 ranges and maximum gas production in the optimal range from7.0 to 8.0 (Perkoulıdıs and Moussıopoulos, 2017).

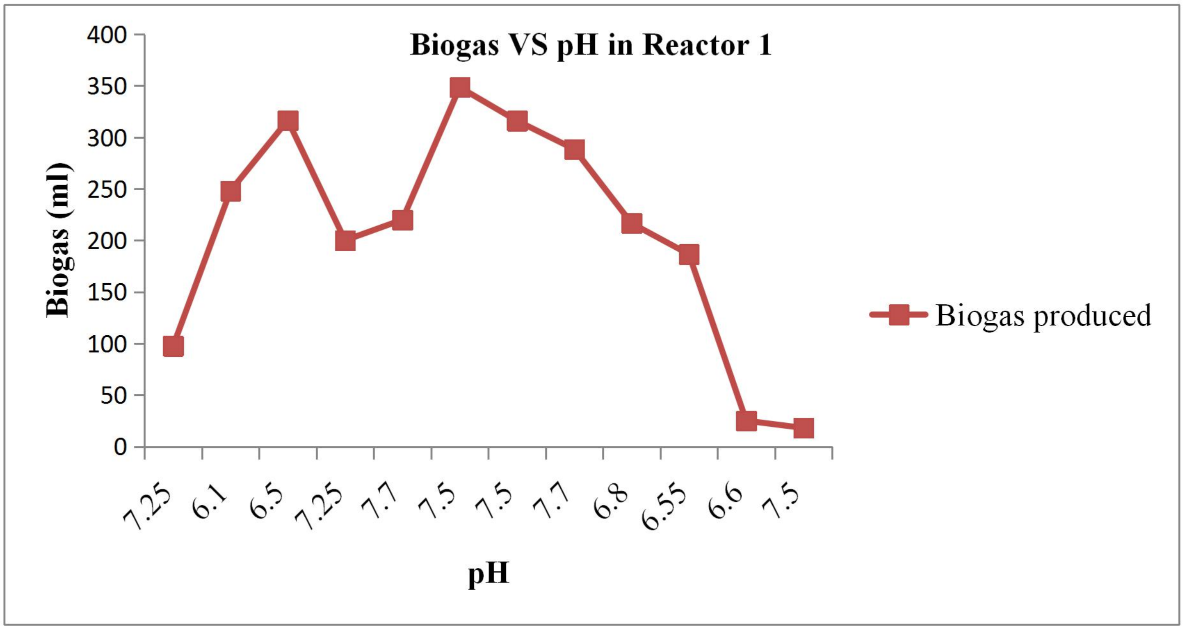

Figure 10: Biogas produced per a day versus to pH of AD in Reactor 1.

The pH during the process was found between 6.1 –7.7. pH analysis was carried out every 23 days. The FW loaded had a pH of 7.25 and the final slurry had a pH of 7.5. At the end of 23 days fig 10.The highest biogas was produced at pH of 7.5 which indicate in the optimum range of pH value that feasible for biogas production in AD. But small amount of biogas was yield at the last day of 21 due to FW nutrients that needed for bacteria activities was completed.

The fall of pH during the first few days of digestion due to the high volatile fatty acids formation (Perkoulıdıs and Moussıopoulos, 2017).based on that, the pH of the treatment was lower at day 2 -4 which might be due to the formation of acids by acidogenic bacteria. However it was increasing as the time of incubation increased. This may be due to digestion of volatile acids and nitrogen compounds through mutagenic bacteria activities. Generally the pH was between 6.1 and 7.7 (fig 10).

Increase in pH value of the substrates through AD my endorsed due to production of alkali compounds, such as ammonium ions during the degradation of organic compounds in the digester. pH Reduction in the substrate before feed in to the AD machine was controlled by addition of sodium bicarbonate($NaHCO_3$) as a buffer solution the pH was adjusted to 6.5-7.5 by adding buffer system in the digester for substrate mixture diverting from normal pH before start of digestion in this experiment as reported by Ziauddin and Rajesh, (2015) NaOH & $NaHCO_3$ added to slurry for the purpose of increase/adjust pH value at optimum range .Compare of the initial, adjusted and final pH of the AD reactor was shown in fig.10

2. **Daily biogas yield versus pH measured in reactor 2**

Daily biogas production in (ml), identification based on pH variability from the combination of inoculums, water and FW in the ratio 1:3:1 in set 2 (reactor2) was adjusted as the following(table 11)

Table 11: Daily biogas production versus pH in reactor 2.

Day	1st round		2ndround		Average	
	pH	Biogas(ml)	pH	Biogas(ml)	PH	Biogas(ml)
1	7.1	102	7.3	90	7.2	96
3	6.4	246	6.6	250	6.5	248
5	7.2	333	6.8	313	7	323
7	6.9	300	6.7	296	6.8	298
9	6.8	252	6.6	231	6.7	241.5
11	7.5	311	7.25	300	7.4	305.5
13	7.5	262	7.5	265	7.5	263.5
15	7.58	200	7.6	205	7.6	202.5
17	7.7	125	7.8	125	7.8	125
19	7	90	6.5	85	6.8	87.5
21	6.5	25	6	32	6.3	28.5
23	7.5	16	7.3	19	7.5	17.5
average	6.86	204.18	6.69	185.58	6.74	194.88

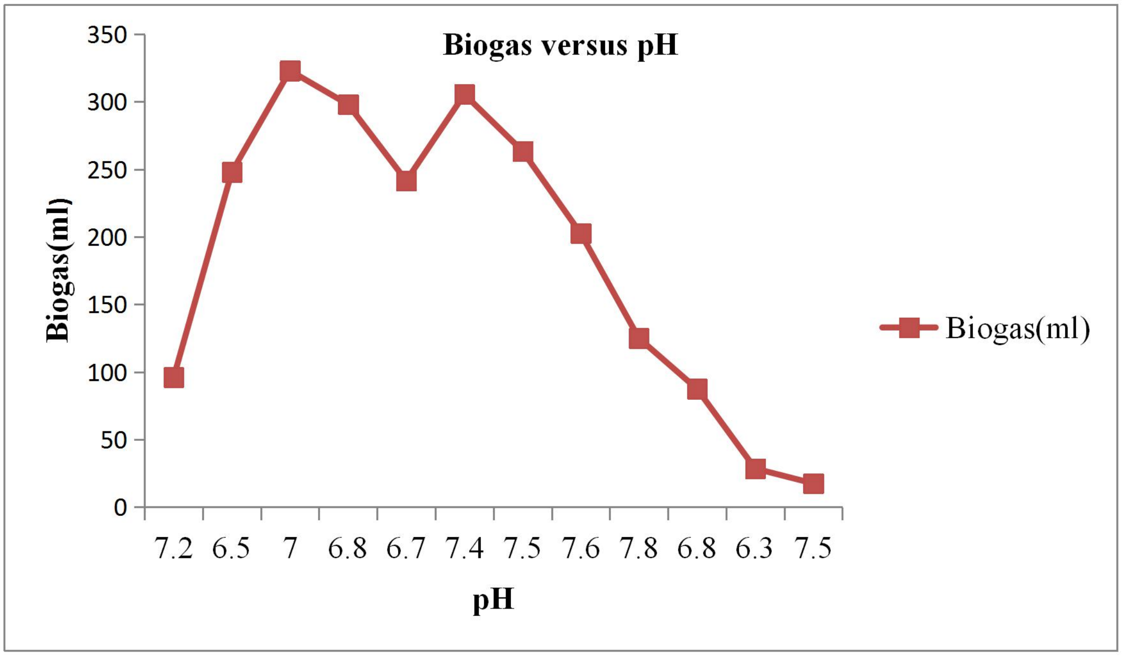

Figure 11:pH measured with in biogas produced in reactor 2 AD.

From the experimental analysis fig.11 the maximum biogas of AD account to 323ml was produced at 7.0 pH value since day 5, in the case of desirable PH and enrichment of nutrient content stage that required for microbial growth and activities. While fluctuation ordered biogas yield was observed in AD, due to unstable pH in the digestion system. The minimum amount of biogas in AD was produced at 7.5 pH value at the end day (23day), due to FW nutrients that needed for methanogenic bacteria activities was completed.

5.2. Biogas composition

A. Set 1 (reactor1) average of biogas composition.

The determination of biogas composition of the digesters was shown in the figure 17 and the composition of methane, carbondioxide, hydrogen sulphides and oxygen was noticed in ml and percentage by using automatic methane potential test system (Gas detector geotechnical instruments GA).

Table 12: Daily biogas produced composition characterization in reactor1.

	Biogas composition							
Date	CH_4		CO_2		O_2		H_2S	
	ml	%	ml	%	ml	%	ml	%
1	48.50	48.18	47.5	48.75	2.50	2.54	0.25	0.5
3	87.50	49.59	134	49.20	2.75	1.10	0.25	0.10
5	152.50	57.01	134	42.189	1.25		1.25	0.40
7	121	61.16	87.5	38.02	0.75	0.40	0.75	0.40
9	87	58.68	87.5	39.65	1.75	0.40	1.75	0.52
11	163	57.59	145.5	37.21	2	0.58	1	0.29
13	219.50	62.14	118.5	37.21	1	0.32	1	0.32
15	231.50	62.19	106	37.03	1.25	0.50	1.25	0.39
17	215	62.11	80	36.35	1	0.69	1.5	0.85
19	186.50	61.04	67	37.31	1.25	0.82	1.25	0.82
21	96.50	56	11	41.31	0.50	2	0.5	2
23	10.50	45.65	11	47.83	0.50	2.17	1	4.34
Total	1618	639.72	1016.5	440.25	16	5.73	10.75	6.61
Average	134.83	58.16	92.41	40.02	1.45	0.93	0.97	0.60

B, Set 2 (reactor2) average of biogas composition.

Table 13: Average of daily biogas produced composition characterization.

	Biogas composition							
Date	CH4		CO2		O2		H2S	
	cH4(ML)	CH4%	ML	%	ML	%	ML	%
1	43.5	45.26	50.50	52.64	2	2.09	0	0.10
3	120	48.39	125.50	50.60	2	0.80	1	0.30
5	169	52.28	151	46.77	2	0.62	1	0.30
7	166.5	55.88	129.50	43.44	1.25	0.42	0.75	0.25
9	134.5	55.71	104.50	43.25	1.50	0.61	1	0.41
11	175.5	57.47	128	41.87	1.75	0.57	1.25	0.41
13	162.5	60.23	99	39.00	1	0.37	1	0.37
15	114.5	56.52	88	43.46	1	0.49	1	0.49
17	69	55.20	53	42.40	1	0.80	1.5	1.60
19	51	58.23	34.50	39.47	1	1.14	1	1.14
21	17	57.68	11	49.68	0.50	1.78	1	3.34
23	7.5	48.38	8	51.12	0.12	0.35	0.12	0.35
Total	1214	660.89	988.50	508.91	15.12	10.09	10.62	9.11
Average	110.36	55.07	82.37	42.40	1.26	0.84	0.88	0.75

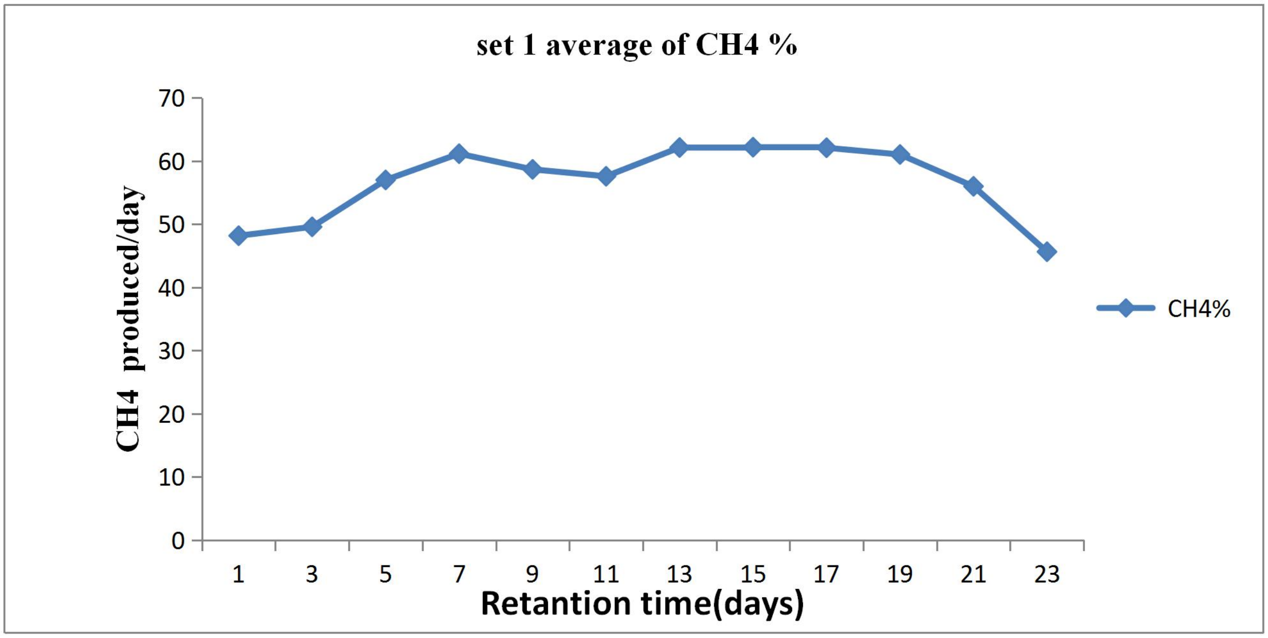

Figure 12:Production rate of methane gas percentage per a day in reactor 1.

The peak line that down ward at day 11 was formed due to the temperature of AD is decreased. While maximum amount of methane gas account to 62.19,62.14 and 62.11 were occurred at day 15,13 and 17 respectively due to favorable temperature and PH range for AD methanogenic bacteria activities.

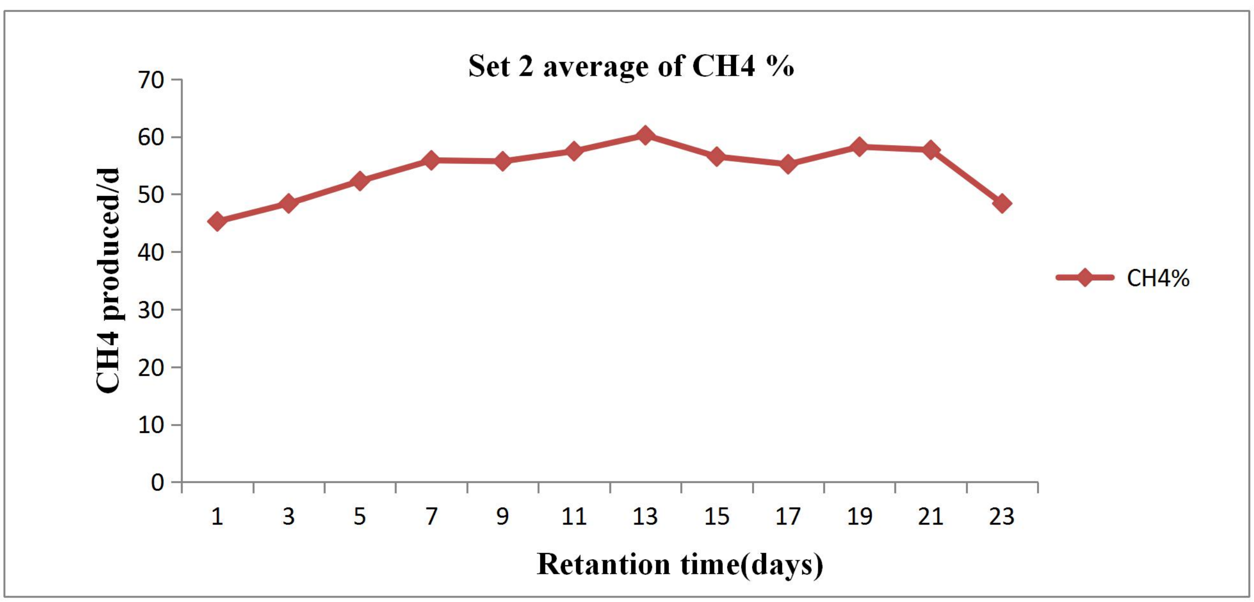

Figure 13: Production rate of methane gas percentage per a day in reactor 2.

In reactor 2, it can be seen that the gas production rate increased from the initial day until the 8 day. in addition to this the maximum amount of methane gas account to 60.239% was yield at the maximum of peak that vied from date 13, due to optimum range of temperature and PH that available for methanogenic bacteria activities was obtained in AD process, but at day 17 there was fail down symbol observed from the peak line, due to temperature fluctuation in the case of electrical interruption . But the least methane gas which account to 45.213% was obtained at day 1,due to the microorganisms responsible for the process were completely inactive in hydrolysis stage. In reactor 1 the total amount of methane gas produced was about 134.83ml/day using FW. In reactor 2 the total amount of methane gas produced was about 110.36ml/day using FW.

In reactor 1 the feed concentration of 28.17% TS, the maximum VS degradation efficiency of 80% and maximum biogas yield of 1.983ml/g VS fed was achieved in 23 days HRT. The maximum methane yield in the reactor was 62.198%/day.

In reactor 2 the feed concentration of 18.79% TS, the maximum VS degradation efficiency of 78.1% and maximum biogas yield of 1.66ml/g VS fed was achieved in 23 days. And the maximum methane yield in the reactor was 60.24%/day.

In reactor 1 the average biogas produced was 1.27ml/g VS/d with an average of methane gas yield in the reactor was 58.156% or 134.83ml/d (0.767 CH4 l /kg Vs.) and HRT of 23 days. Which had converted to methane amount yield/annum was 279.99L /kg VS.

In reactor 2 the average biogas produced was 2.756ml/g VS/d with an average of methane gas content in the reactor was 55.074% or 110.36ml/d) and HRT of 23 days.

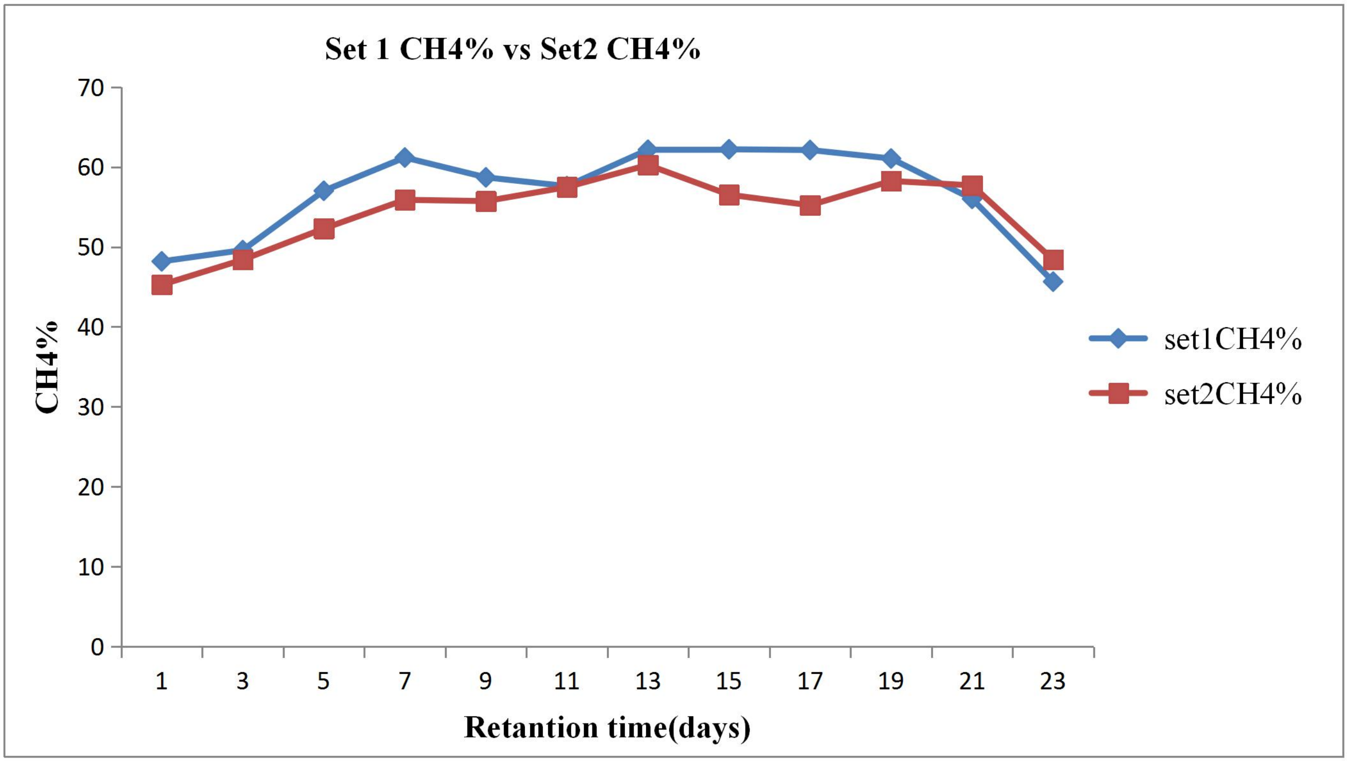

Figure 14: methane percentage per a day in reactor 1 and 2 comparison.

In generally in this study based on data analyzed at lab scale AD of biogas production from FW. There was estimation of FW generation rate, amount of biogas and methane production and recoverable of electrical potential energy from Jimma University FW generation rate was noticed according to the following.

1 .Total population……..15580

2 .Total FW/d…………2,035.63kg

3. Total FW/y …..........752558.46kg (752.55846tone)

4. Total biogas/d from 225g &150g FW respectively

a. Reactor (set) 1.▼…… 223.90ml (0.02239m^3)

b. Reactor (set) 2…………194.88ml (0.019488m^3)

5. Total biogas/y

a. Reactor (set) 1………..81723.5ml (0.0817235m^3)

b. Reactor (set) 2…………71131.2ml (0.0711312 m^3)

6. Total CH4/d

a. Reactor (set) 1……..134.83ml (0.013483m^3)

b. Reactor (set) 2………110.36ml (0.011036m^3)

7. Total CH4/y

a. Reactor (set) 1….49212.95ml (0.04921295m^3)

b. Reactor (set) 2…..40281.4ml (0.0402814m^3)

8. Electrical energy recovered from.

a. Reactor 1…………..0.053kwh/day and 19.43kwh/year

b. Reactor 2…………...0.0043kwh/day and 1.57kwh/year

9. By product organic fertilizers (residue) from

a. Reactor 1…………..93.02 g residue

b. Reactor 2…………...62.01g residue

Hence in lab scale experimental analysis the electrical potential energy recovered from FW in reactor 1 and 2 was indicated in number 8.finally since based on this study result we can produce 45096.648m^3/d and 164602.764m^3/y amount of methane gas and recover 17677.886kwh/d and 6452428.349kwh/y amount of electrical potential energy and 0.84tones/d and311.12tones/y organic fertilizers from 2.04tones/d and752.558tones/y post consumer of FW generate from Jimma university. In generally the electric energy obtained from FW can recover the hydro electric energy used for cooking by stand up when the normal electric power are interrupted.

CHAPTER SIX

6. CONCULUTION AND RECOMANDATION

6.1. Conclusions

The study was estimate FW generation rate from Jimma University which account to 2.036tonns/d and 752.558tonnes/year. Biogas production from FW through an AD of 5L capacity digester in the lab scale was evaluated for the duration of 23 days. The total amount of biogas production recorded up to 23 days was about 2463ml (58.16% CH4) in reactor 1 and 2266.5ml (55.07%CH4) in reactor 2.

The loading rate during this period was 225g/Land 150g/L dried substrate which mixed with tap water and inoculums that added to reactor 1 and reactor 2 digester. FW getting converted into biogas not only becomes an alternative source of energy but also helps in reducing the methane production from organic waste which is one of the green house gases that cause for global warming. From this study it is evident that FW can become a good feedstock for the biogas production. FW contains more biodegradable solids 28% inreactor1 and 18% in reactor 2 with higher volatile solids 83% in reactor 1 and 78% in reactor 2.

Increase in moisture content of the dig estate was 77% and 83% decrease in VS was observed after 23 days. Since FW contains 80% VS in reactor 1, has a great potential of biogas production and can be used easily and potentially as a raw material for biogas production. The volatile solids finally reduced to 67.7 and 65.07 in reactor 1 and 2.As FW is used, it contains enough carbohydrates and less cellulose and lignin content. Thus the removal of carbon content was fast. At the time of gas production the number of microbes had increased. Maximum microbial counts were observed during peak of biogas production.

The lab average temperature was between 27- 35^{0}C.pH during the process was found between 6.2-7.5. Hence post consumer of FW generated from Jimma university can be used to produce 45096.65m^3/d and 164602.76m^3/y amount of methane gas and capacity to recover 17677.89kwh/d and 6452428.35kwh/y amount of electrical potential energy from2.036tonns/d and752.558tones/y FW, instead of going to the dump yards in Jimma university area, FW holds highest potential of economic exploitation as it contains high amount of carbon and volatile solids that can be converted into biogas. The biogas technology not only provides the energy but also gives final digested slurry which can be used in composting/vermin composting and later used in the soil as a nutrient supplement. The slurry can be recycled back into the digester mixed with fresh waste. Thus biogas from FW can help in achieving social, economic and environmental benefits sustainability due to rise in LPG prices in Ethiopia. The process needs a lot of care with respect to the physical and biochemical changes like pH, temperature, and proper anaerobic condition

6.2. Recommendations

Its recommend to governmental and NGO to convert large FW generation to electric potential rather disposed to land fill may can support as alternative sources of electrical potential energy recoverable which can reduce shortage of electrical energy supply and LPG costs.

And also it’s better to use by product organic fertilizers for agricultural application which beneficial to sustainable development of social, economical and environmental feasibility.

Jimma university administration and community should aware to accelerate in renewable energy recover technology from food waste and other organic waste.

Jimma University should provide adequate skill training and instrumental supply for renewable energy development.

7. References

Adebayo, A.O., Jekayinfa, S. O and linke, B. (2014) *Anaerobic co-digestion of cattle slurry with maize stalk at mesophilic temperature*.

Ahamed, J., Raiyan, M. and Hossain, M. (2016) 'Production of biogas from anaerobic digestion of poultry droppings and domestic waste using catalytic effect of silica gel.', *of Automotive &* 13(2), pp. 3503–3517. Available at: http://umpir.ump.edu.my/16183/1/fkm-2016-17_Ahamed et al.pdf.

Akorede, M. F. *et al.* (2017) 'current status and outlook of renewable energy development in nigeria', 36(1), pp. 196–212.

Al-Zuahiri, F. *et al.* (2015) 'Biogas Production from Solid State Anaerobic Digestion for Municipal Solid Waste', *Chemical Engineering Transactions*, 43, pp. 2407–2412. doi: 10.3303/CET1543402.

Arsova, L. (2010) 'Anaerobic digestion of food waste : Current status , problems and an alternative product', M.S. Degree Thesis n Earth Resources Engineering, Columbia University,(May),pp.1–67Availableat: http://www.seas.columbia.edu/earth/wtert/sofos/arsova_thesis.pdf.

Awasif, M., Maskhoot, J. and Saadi, A. (2016) 'Design and Production of Methane Gas from Food Waste using Anaerobic Digestion', *Design and Production of Methane Gas from Food Waste using Anaerobic Digestion*, 1(8), pp. 77–82.

Barrington, Choiniere, D., Trigui, M., and Knight, W. (2002) 'Effect of carbon source on compost nitrogen and carbon losses. Bioresource Technology, 83:189-194', 5(02), pp. 247–253.

Batori, V. and Nair, R. (2017) *Food waste: Potential source for bioenergy and bio-products*. Available at: https://www.mycorena.com/Food_waste.docx.pdf.

Chesshire, M. (2013) *Anaerobic Digestion of Food Waste*, *U.S. Environmental Protection Agency Region 9*.

Esposito, G. *et al.* (2012) 'Anaerobic co-digestion of organic wastes', *Reviews in*

Environmental Science and Biotechnology, 11(4), pp. 325–341. doi: 10.1007/s11157-012-9277-8.

Gashaw, A. (2016) 'Co-digestion of municipal organic wastes with night soil and cow dung for biogas production : A Review', 15(2), pp. 32–44. doi: 10.5897/AJB2015.14705.

Genet, W., Wolka, K. and Melaku, B. (2015) 'Exploring selected plant nutrient in compost prepared from food waste and cattle manure and its effect on soil properties and maize yield at', ??? ??? doi: 10.1186/s40068-015-0035-0.

Gerardi, M. H. (2003) 'The microbiology of anaerobic digesters (Vol. Volume 3). Chichester: John Wiley'.

Ghouali, A., Sari, T. and Harmand, J. (2015) 'Maximizing biogas production from the anaerobic digestion', 36, pp. 79–88.

guidelines for solid waste management assessment (baseline survey) in secondary cities and small towns in asia and the pacific (2010).

Holliger, C., Fruteau de Laclos, H. and Hack, G. (2017) 'Methane Production of Full-Scale Anaerobic Digestion Plants Calculated from Substrate's Biomethane Potentials Compares Well with the One Measured On-Site', *Frontiers in Energy Research*, 5(June), pp. 1–9. doi: 10.3389/fenrg.2017.00012.

Horaginaman, S.M, Williams, M.A., Edward, R., R. and M. and Madar, I. N. (2011) 'Biological solid waste treatment. Proceedings of the Waste Safe —2nd International Conference on Solid Waste Management in the Developing Countries 13-15 February 2011, Khulna, Bangladesh'.

Iyagba, E. *et al.* (2017) 'The study of cow dung as co-substrate with rice husk in biogas production The study of cow dung as co-substrate with rice husk in biogas production', 4(January), pp. 861–866.

Joshi, A. *et al.* (2017) 'Study on Electricity Generation through biogas on small scale', Vol. 6(Issue 4), pp. 6662–6669. doi: 10.15680/IJIRSET.2017.0604081.

Karagiannidis, A. (2012) ‘Waste to energy’, (April), pp. 1–44.

Khalid, A. *et al.* (2011) ‘The anaerobic digestion of solid organic waste’, *Waste Management*. Elsevier Ltd, 31(8), pp. 1737–1744. doi: 10.1016/j.wasman.2011.03.021.

Krátký, L., Jirout, T. and Nalezenec, J. (2012) ‘Lab-scale technology for biogas production from lignocellulose wastes’, *Acta Polytechnica*, 52(3), pp. 54–59.

Li, Y. *et al.* (2018) ‘Influence of feed / inoculum ratios and waste cooking oil content on the mesophilic anaerobic digestion of food waste’, 73, pp. 156–164.

Liu, C. *et al.* (2018) ‘Bioresource Technology Biogas production and microbial community properties during anaerobic digestion of corn stover at di ff erent temperatures’, 261(October 2017), pp. 93–103.

Ma, Y., Yin, Y. and Liu, Y. (2017) ‘Bioresource Technology New insights into co-digestion of activated sludge and food waste : Biogas versus biofertilizer’, *Bioresource Technology*. Elsevier Ltd, 241, pp. 448–453. doi: 10.1016/j.biortech.2017.05.154.

Mkiramweni, L. L. N., Msaki, P. and Mshoro, I. B. (2005) ‘Use of hot air engine to generate electricity from biogas : a critique for rural development in tanzania’, *Tanz. J. Sci*, Vol. 31(2).

Mohan, S. and Jagadeesan, K. (2013) ‘Production of Biogas by Using Food Waste’, 3(4), pp. 390–394.

Muršec, B. and Vindis, P. (2010) ‘Construction of Device for Laboratory Production of Biogas’, *Strojarstvo*, 52(3), pp. 363–367.

Mustafa, M. Y., Calay, R. K. and Román, E. (2016) ‘Biogas from Organic Waste - A Case Study’, *Procedia Engineering*. Elsevier B.V., 146(1877), pp. 310–317. doi: 10.1016/j.proeng.2016.06.397.

Muthu, D. *et al.* (2017) ‘Production of Biogas from wastes Blended with CowDung for Electricity generation-A Case study’, in *IOP Conference Series: Earth and Environmental Science*. doi: 10.1088/1755-1315/80/1/012055.

Mydin, M. A. O. *et al.* (2014) 'Generating Renewable Electricity from Food Waste', *E3S Web of Conferences*, 3, p. 01012. doi: 10.1051/e3sconf/20140301012.

Mydin, M. A. O. *et al.* (2014) 'Generating Renewable Electricity from Food Waste', 2, pp. 1–7.

Onojo, O. . *et al.* (2013) 'Estimation Of The Electric Power Potential Of Human Waste Using Students Hostel Soak-Away Pits .', *American Journal of Engineering Research (AJER)*, 2(09), pp. 198–203.

Overview, A. (2015) *Dairy Anaerobic Digestion Systems and their Impact on Greenhouse Gas and Ammonia Emissions*.

Perkoulıdıs, G. and Moussıopoulos, N. (2017) 'Energy recovery potential by utilising campus food waste in a biogas plant', *Energy recovery potential by utilising campus food waste in a biogas plant Perkoulıdıs*, (September).

Pessuto, J., Godinho, M. and Dettmer, A. (2015) *Biogas production from tannery wastes - Evaluation of isolated microorganisms effect*, *XXXIII IULTCS Congress*.

Pham, T. P. T. *et al.* (2015) 'Food waste-to-energy conversion technologies: Current status and future directions', *Waste Management*. Elsevier Ltd, 38(1), pp. 399–408. doi: 10.1016/j.wasman.2014.12.004.

Sluiter.A, B. Hames, D. Hyman, C. Payne, R. Ruiz, C. Scarlata, J. Sluiter, D. Templeton, and J. W. (2008) 'Determination of Total Solids in Biomass and Total Dissolved Solids in Liquid Process Samples'.

Somashekar, R. K., Verma, R. and Naik, M. A. (2014) 'Potential of biogas production from food waste in a uniquely designed reactor under lab conditions', *International Journal of Geology*, 2(April), pp. 2348–254.

Surroop, D. and Mohee, R. (2012) 'Technical and Economic Assessment of Power Generation from Biogas', 30, pp. 108–112.

Teodorita, Al Seadi, Dominik Rutz, Heinz Prassl, Michael Kottner, Tobias Finsterwalder, S.

V. and R. J. (2008) 'Biogas Handbook. Published by University of Southern Denmark Esbjerg, Niels Bohrs Vej 9-10.'

US-EPA (2014) 'Food Waste Management Scoping Study', *office of resource conservation and recovery*,(April), pp. 1–9. Available at: https://www.epa.gov/sites/production/files/2016-01/documents/msw_task11 2_foodwastemanagementscopingstudy_508_fnl_2.pdf.

Velmurugan, B. and Ramanujam, R. A. (2011) 'Anaerobic Digestion of Vegetable Wastes for Biogas Production in a Fed-Batch Reactor', *Int. J. Emerg. Sci*, 1(3), pp. 478–486.

Yadvika *et al.* (2004) 'Enhancement of biogas production from solid substrates using different techniques--a review'.

Ziauddin, Z. and Rajesh, P. (2015) 'Production and Analysis of Biogas from Kitchen Waste', *International Research Journal of Engineering and Technology (IRJET)*, 2(4), pp. 622–632.

Zupančič, G. D. and Grilc, V. (2007) *Anaerobic Treatment and Biogas Production from Organic Waste*, *Management of Organics Waste*. doi: 10.5772/32756.

Appendix of figure and tables

Figure 15: FW data collection.

Figure 16:FW parameters

Figure 17: Biogas composition analysis.

Table 14: List of food types eaten In Jimma University student cafeteria per a week.

s/no	Date/week	Break fast	Launch	Dinner
1	Monday	Rice	Vegetable	Meat
2	Tuesday	Firfer	Peels	Meat with potato
3	Wednesday	Kinche	Lentil	Peels
4	Thursday	Rice	Peels	Meat
5	Friday	Kinche	Peels	Lentil
6	Saturday	Firfer	Meat with potato	Peels
7	Sunday	rice	Peels	Lentil mute

Table 15:FW generation rate at Jimma university from student cafeteria number-2.

Dates/week	Breakfast (kg)	Lunch(kg)	Dinner(kg)	Total kg/d
Thursday	65	100	135	300
Friday	64	115	140	315
Saturday	58	130	138	326
Sunday	56	97	121	274
Monday	63	141	117	321
Tuesday	57	128	139	324
Wednesday	61	135	142	338
Thursday	64	132	140	336
Total Kg/week	488	978	1072	2534

Total number of student considerd-2300, i.e. 2534/2300= o.138kg/p/day,1.102kg/p/w

Table 16:food scraps generation rates From JU student cafeteria(no-2)

Dates/week	Breakfast(kg)	Lunch(kg)	Dinner(kg)	Total kg
Thursday	151	305	312	768
Friday	156	300	304	760
Saturday	150	310	288	748
Sunday	156	291	315	762
Monday	143	308	307	758
Tuesday	145	291	311	747
Wednesday	148	306	303	757
Thursday	145	309	299	753
Total	1194	2420	2439	6053kg

The total numbers of students considered are 6000 i.e.
6053kg/week,6053/7=**756kg/day**,**0.126kg/p/d**

Table 17:food scraps generation rate from JU specialized hospital**.**

Dates/week	Maternity(kg)	Surgical(kg)		Guinean(Kg)	Medical(kg)		Child (kg)	Eyes ward(kg)	Opd(kg)	Total(kg)
		A	B		A	B				
Thursday	13	11	12	14	15	14	11	9	7	104
Friday	11	15	16	12	10	12	13	7	12	108
Saturday	17	14	12	15	13	10	15	10	13	119
Sunday	14	12	15	13	10	12	13	8	11	108
Monday	13	15	12	13	12	11	10	9	9	104
Tuesday	8	10	15	13	12	10	8	8	12	96
Wednesday	9	14	12	11	13	15	12	10	9	104
Thursday	11	12	11	10	12	9	8	8	10	91
total	96	103	105	101	97	93	90	69	83	834

i.e.834kg/week,834/8=104.25kg/day while 104.25/984patient=0.105kg/patient/d which considering total population are 986

Table 18:food scrap generation rate from JU agricultural collage.

Dates/week	Breakfast(kg)	Lunch(kg)	Dinner(kg)	Total(kg)
Wednesday	36	95	100	231
Thursday	31	84	93	208
Friday	38	88	85	211
Saturday	28	80	85	193
Sunday	33	90	91	214
Monday	30	93	94	217
Tuesday	27	92	79	198
Wednesday	40	85	87	212
Total Kg/week	263	707	714	1684

1684kg/week,1684kg/7=**210.5kg/d**, **0.1403kg/p/d. which considering total number of student 1500.**

Table 19:FW generation rate from JU technology institute student cafeteria**.**

Dates/week	Breakfast(kg)	Lunch(kg)	Dinner(kg)	Total(kg)
Wednesday	127	268	275	670
Thursday	130	257	246	633
Friday	134	278	280	692
Saturday	120	245	272	637
Sunday	125	269	276	670
Monday	122	258	270	650
Tuesday	118	266	240	624
Wednesday	126	264	280	670
Total	1002	2105	2139	5246

i.e.5246kg/week, 5246/8=655.75kg/day, 0.14kg/p/d and considering total number of student 4700

Table 20:daily Biogas production composition in reactor1, 1st round**.**

	Biogas composition							
Date	CH4		CO2		O2		H2S	
	ML	%	ML	%	ML	%	ML	%
1	49	49.49	46	46.464	3	3	1	1
3	126	50.4	121	48.4	3	1.2	0	0
5	179	59.66	118	39.333	1	0.3333	2	0.6666

7	63	60	41	39.047	0.5	0.4761	0.5	0.4761
9	111	59.04	73	38.829	1.5	0.7978	2.5	0.644
11	215	55.69	168	43.523	2	0.5181	1	0.2590
13	224	60.54	144	38.918	1	0.2702	1	0.2702
15	239	63.39	136	36.074	1	0.2652	2	0.5305
17	191	61.61290	117	37.741	0.5	0.161	1.5	0.4838
19	182	64.31095	98	34.628	1.5	0.5300	1.5	0.5300
21	15	60	9	36	0.5	2	0.5	2
23	10.5	45.65	11	47.83	1	4.34	0.5	2.17
Total	1594	644.1632	1071	3309.1	15.5	9.5523	13.5	6.860
Average	144.909	58.56029	97.36	39.905	1.4090	0.8683	1.22	0.623

Table 21:Biogas composition characterization in reactor 1, 2nd round

Date	CH4		CO2		O2		H2S	
	ML	%	ML	%	ML	%	ML	%
1	48	46.875	49	51.041	2	2.083333	0	0
3	49	48.780	123	50	2.5	1.016260	0.5	0.20325
5	126	54.354	150	45.045	1.5	0.450450	0.5	0.15015
7	179	62.333	111	37	1	0.333333	1	0.33333
9	63	58.333	102	40.476	2	0.793650	1	0.39682
11	111	59.485	123	41.935	2	0.645161	1	0.32258
13	215	63.740	93	35.496	1	0.381679	1	0.38167
15	224	61	76	38	1.5	0.75	0.5	0.25
17	239	62.601	43	34.959	1.5	1.219512	1.5	1.21951

19	191	57.777	36	40	1	1.111111	1	1.11111
21	182	60	9	36	0.5	2	0.5	2
23	10.5	45.65	11	47.83	0.5	2.17	1	4.34
Total	1298	635.28	915	449.95	16.5	10.78449	8.5	6.36844
Average	118	57.752	83.181	40.904	1.5	0.978371	0.7727	0.5786

Table 22: Biogas composition in reactor 2,1st round

Date	CH4		CO2		O2		H2S	
	ML	%	ML	%	ML	%	ML	%
1	47	46.07843	53	51.960784	2	1.96078	0	0
3	120	48.78048	123	50	2.5	1.01626	0.5	0.203252
5	178	5.45345	153	45.945945	1.5	0.45045	0.5	0.15015
7	163	54.33333	135		1	0.33333	1	0.33333
9	139	55.15873	110	43.650793	2	0.79365	1	0.39682
11	174	55.94855	134	43.086816	2	0.64308	1	0.32154
13	146	55.7251908	114	43.511450	1	0.38167	1	0.38167
15	110	55	88	44	1.5	0.75	0.5	0.25
17	70	56	52	41.6	1.5	1.21951	1.5	1.21951
19	54	60	34	37.777777	1	1.11111	1	1.11111
21	13	56	10	40	0.5	2	0.5	2
23	0	0	0	0	0	0	0	0
Total	1214	596.4781	1006	486.53356	16.5	10.6598	8.5	6.36740
Average	110.36	54.22528	91.45454	44.230324	1.5	0.96907	0.7727	0.57885

Table 23: Daily Biogas production composition

Biogas composition								
Date	CH4		CO2		O2		H2S	
	ML	%	ML	%	ML	%	ML	%
1	40	44.4444	48	53.333	2	2.222222	0	0
3	120	48	128	51.2	1.5	0.6	0.5	0

5	160	51.1182	149	47.603	2.5	0.798722	1.5	0.4573
7	170	57.4324	124	41.891	1.5	0.506756	0.5	0.1689
9	130	56.2770	99	42.857	1	0.432900	1	0.4329
11	177	59	122	40.666	1.5	0.5	1.5	0.5
13	161	60.7547	102	38.490	1	0.377358	1	0.3773
15	119	58.0487	88	42.926	0.5	0.243902	1.5	0.7317
17	68	54.4	54	43.2	0.5	0.4	2,5	2
19	48	56.4705	35	41.176	1	1.176470	1	1.1764
21	21	59.375	12	59.375	0.5	1.5625	1.5	4.6875
23	21	60	13.5	38.571	0.25	0.714285	0.25	0.7142
Total	1235	665.321	971	531.29	13.75	9.535118	2.75	11.246
Average	102.91	55.4434	80.916	44.274	1.1458	0.794593	0.93	0.9372