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Production of biogas from Water Hyacinth/"Emboch Arem" through anaerobic Co-digestion with cow dung: Case study on Lake Tana

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Abstract: *Biogas is produced by the breakdown of organic material through anaerobic digestion of microbial activity. Biogas can be used for production of heat and electricity and upgraded biogas can be delivered to the natural gas grid or used as vehicle fuel.*
The main objective of the study was to produce biogas from Water hyacinth weed co- digestion with Cow dung, along with optimizing the water hyacinth and cow dung substrate co-digestion ratio with variable parameters.

The water hyacinth composition investigated small amount of Lignin (about 3.8%) and contains high amounts of cellulose (21.2%) and hemicellulose composition with carbon to nitrogen ratio of 47.87%, which is generally a better quality for biogas production.
The Total organic carbon content of the water hyacinth substrate was 86.17% of the Total solid and 84.34% for cow dung. This implies that water hyacinth can serve as an important feedstock for biogas production. The sugar concentration of pre-treated water hyacinth sample results 5.23% of sugar content in 100g sample.
The highest biogas production from 0.7l Volume slurry was 1,065ml for substrate mix of 25 % WH+75% Cow dung with 7.3 pH, 27.5%Rumen fluid and 35^{O}C and the lowest is 253 ml for 100% water hyacinth with 6.80 pH, 5%Rumen fluid and 30^{O}C; on the other hand the highest methane content (34%) is obtained with 38.5%Vol CO_2 and H_2S 0.1ppm from 100%Cow dung and the lowest methane content of 0% with 43%Vol and H_2S 13ppm from 100%Water hyacinth. Co-digestion of water hyacinth with cow dung increased Methane yield by 22.47% (75% cow dung), 17.47% (50% cow dung) and 4.43% (25% cow dung) over water hyacinth alone.
From this study it can be conclude that Water Hyacinth has been shown a potentially useful substrate for the production of biogas by Co-digestion with Cow dung.

Key words: Biogas, Bio-digester, Cow dung, fixed solid, Heavy metals, lignocellulos, Methane, Water Hyacinth, Total organic carbon, Volatile solid

1. INTRODUCTION

Historical evidence indicates that the biogas process is one of the oldest technologies. Biogas advanced with scientific research and, in the 17th century, Jan Baptista Van Helmont established that flammable gases evolved from decaying organic matter (Stefan and Kozani, 2014). Humphrey Devy in the early 1800's noticed that methane was present in farm yard manure piles.

Water Hyacinth (Eichhornia crassipes Martius) (also called Emboch arem: Amharic) is a monocotyledonous free-floating perennial freshwater aquatic plant, belonging to the family Pontederiaceae, related to the lily family (Liliaceae) and the exact time and place of introduction has been debated, but it is a native of South America, Brazil and Ecuador region, with broad, thick, glossy, ovate leaves, which has become an invasive plant species on Lake Victoria in Africa after it was introduced by Belgian colonists to Rwanda to beautify their holdings (Anjanabha B. et al., 2010).

The water hyacinth has also appeared in Ethiopia, where it was first reported in 1965 at the Koka Reservoir and in the Awash River, where it has managed to bring it under moderate control at considerable cost of human labor. Other infestations in Ethiopia include many bodies of water in the Gambela Region, the Blue Nile from Lake Tana into Sudan (Rezene 2005).

Water hyacinth invades fresh water habitats and is listed along with some of the worst weeds. It cause blockage of irrigation channels, get entangled with motorboat rotors, making fishing difficult, and out-compete almost all other species growing in their vicinity thereby decreasing biodiversity. They also accelerate the process of evaporation from water bodies and sometimes can be a breeding ground for disease causing insects and pests (Jimenez et al., 2014).

The three commonly used control methods against water hyacinth infestations are physical, chemical, and biological controls (Fadairo A. and Fagbenle R. 2014). Currently physical methods is applied in Lake Tana water hyacinth controlling mechanism and waste is dumped in nearby land area, However, As a result of partial anaerobic decay the wastes emit huge amount of CH_4 and CO_2 (greenhouse gasses) to the atmosphere together with NH_3 and H_2S-noxious gases, causing environmental and health problems (Werner K., 2011). Moreover the wastes affect aquatic systems by depleting dissolved oxygen due to the biochemical strength of the wastes if washed with flood water. However, because of its extremely high rate of development, Eichhornia crassipes is an excellent source of biomass, one hectare of standing crop thus produces more than 70,000 m^3 of biogas. One kg of dry matter can yield 370 liters of biogas, giving a heating value of 22,000 kJ/m^3 (580 Btu/ft^3) compared to pure methane (895 Btu/ft) (James A. 1983).

Biogas is produced by Microorganisms, which break down organic material through anaerobic digestion. The biogas can be used for production of heat and electricity and upgraded biogas can be delivered to the natural gas grid or used as vehicle fuel.

Njogu et al. (2015) found that Biogas usually contain 49% - 53% methane (CH_4), 30% - 33% carbon dioxide (CO_2), 5% - 6% nitrogen (N_2) and traces of hydrogen sulphide (H_2S).

1.1. Statement of the problem

Water hyacinth absorbs heavy metals from lake, and as the harvested weed biomass used for biogas production heavy metals available above its limited value will be disturbed the biochemical reaction of anaerobic digestion systems.

Since the weed is unfamiliar for Lake Tana area and water hyacinth weed variety is also unknown, it faces difficulty for utilization in to biogas; the water hyacinth weed is also a lignocellulosic plant which is difficult to use directly as raw material for biogas production.

Currently the Cultural, Economic, Environmental, Tourism and Religious center of United Nation Educational, Scientific and Cultural Organization (UNESCO) heritage Lake Tana and the Blue Nile river stream face's a risk of disappearance in a very short period of time by water hyacinth weed due to lack of practical activity that will utilize either directly or indirectly the weeds biomass.

Even if biomass waste is an energy source, lack of technology and skilled manpower about the conversion of this water hyacinth in to biogas leads to being an accumulated waste.

1.2. Objectives of the project

1.2.1. General objective

- To Convert water hyacinth weed into biogas through anaerobic co-digestion with cow dung

1.2.2. Specific objectives

- To optimize parameters such as Substrate blending ratio, pH, Rumen fluid and Temperature for optimal biogas product yield
- To identify the composition water hyacinth and the effect of cow dung blends
- To analyse the potential of water hyacinth biomass for biogas production
- To analyse the sugar content of water hyacinth substrate
- To identify the methane composition of produced biogas

1.3. Significance of the study

Water hyacinth has long been seen as an invasive species and considerable amount of resources have been required for their control. However, it has identified a certain qualities with small amount of Lignin (about 3.8 %) and high amounts of cellulose (21.2%) composition; which is a better quality for effective utilization of biogas energy.

The nature of water hyacinth available in the Lake Tana and its potential for utilization in to biogas being identified that helps for decision in order to utilize it. The better condition of parameters and blending ratio of substrate for optimal biogas yield was also investigated, so that this study will help as a reference for further study.

Water hyacinth elimination is amendatory action by itself for the existence of Lake Tana, but this study initiated governments and other stockholders to converting of this waste into useful biogas product and by products for fertilizer which is an advantage for compensation energy shortage from national grid by alternative onsite biogas energy production. The productions of biogas from water hyacinth weeds are also important in aquatic ecosystem protection with useful soil fertilizer beyond its energy generation.

2. LITERATURE REVIEW

2.1. Description of biogas

Biogas technology is an alternative energy source which utilizes various organic wastes in order to produce Biogas (cooking, heating and lighting), mineralized water and organic fertilizers.

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint (Lahlou, 2017).

Biogas can be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials. Biogas is primarily methane and carbon dioxide and may have small amounts of hydrogen sulphide moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat (Bahadhur and Engg, 2016).

2.2. Biogas production process

The biochemical degradation of organic substrates to biogas has been a promising option due to its economic and environmental feasibility compared to other biofuels. Anaerobic digestion is a biological process occurring through defined steps. The first stage is the hydrolysis of complex organics (i.e., carbohydrates, lipids and proteins) into soluble compounds; it is recognized as the process rate limiting step, so that it is often promoted by adequate substrate pre-treatment (Sudhakar et al., 2013).

Better yields of biogas are obtained using mixture of animal waste and lignocellosic waste since the animal waste particularly the cow dung has the significant syntrophic mechanism enhanching bacteria (Pachaiyappan et al., 2015). Substrates highly rich in lipids and easily-degradable carbohydrates exhibit higher methane potential than lignocellulosic materials.

Table 2.1 Maximal theoretical methane yields for substrate constituents, (Cesaro and Belgiorno, 2015).

Constituent	Methane yield(Nm^3/t_{TS})
Carbohydrates	395 - 400
Raw protein	497
Raw fat	816 - 850
Lignin	0

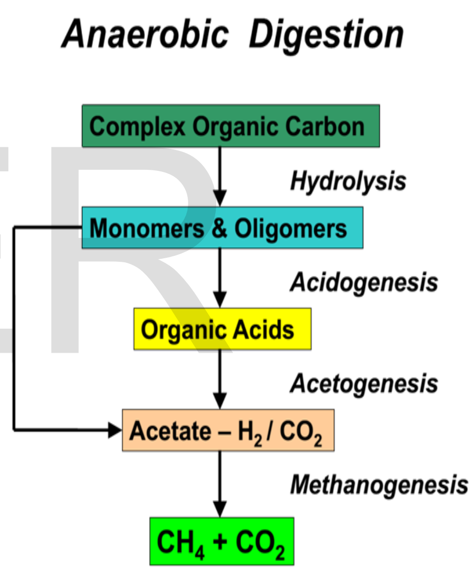


Figure 2.1 block diagram of biogas production through anaerobic digestion (Gozde et al., 2018).

2.3. Chemistry of biogas production

The anaerobic digestion process involves a large number of microorganisms, which convert the feedstock to the methane and carbon dioxide rich biogas through a series of biochemical reactions These microorganisms include hydrolytic bacteria, acid forming bacteria (acidogens), acetic acid-forming bacteria (acetogens) and methanogenic bacteria (methanogens). Originally, anaerobic digestion was perceived as a two stage process involving the sequential action of acid forming and methane forming bacteria. Now, it is known to be a complex fermentation process brought about by the symbiotic association of different types of bacteria (Gozde et al., 2018).

The principal reaction sequences can be classified into four major groups involving the following:

- ✓ Hydrolysis

Firstly the biomass having complex compound such as fats, proteins, carbohydrates etc. are broken down into simple water soluble organic compounds through the influence of water called hydrolysis. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. i.e. polysaccharides are converted into monosaccharide and proteins are split into peptides and amino acids. The rate at which hydrolysis takes place is governed by substrate availability, bacterial population, density, temperature and pH (Okonkwo et al., 2013).

- ✓ Acidogenesis/Fermentation

Acidogenesis is the 2nd step of biogas production, in which the acidogenic bacteria further break down the products (the soluble monomers molecules) of the first step, into short chain organic acids (volatile fatty acids i.e. Lactic, propionic, and butyric acids, NH3, H2)

- ✓ Acetogenesis/dehydrogenation

Organic acids, alcohols and ketones can be transformed to acetate, carbon (II) oxide and hydrogen gas by acetogenic bacteria in an anaerobic digestion of wastes. Acetogenic bacteria convert fatty acids (e,g. propionic acid, butyric acid) and alcohols into acetate, hydrogen and carbon(II) oxide, which are used by the methanogens. Hence, ethanol, propionic acid and butyric acid are converted to acetic acid by the following reactions (Okonkwo et al., 2013).

- ✓ Methanogenesis

In this stage the anaerobic bacteria called as methane formers converts the organic acids formed in stage III into biogas having its main constituents as methane and carbon dioxide with other small trace of H2S, H2 and N2 etc. These methane formers are sensitive to pH changes (Stefan and Kozani, 2014).

2.4. Key microorganisms of the methane fermentation process

Conversions of complex organic compounds to CH_4 and CO_2 are possible owing to the cooperation of four different groups of microorganisms. These microorganisms may be counted among: primary fermentation bacteria, secondary fermentation bacteria (syntrophic and acetogenic bacteria) and two types of methanogenes belonging to domain Archaea. The bacteria belonging to domain Archaea, which are involved in the production of methane exhibit synergistic relationships with other populations of microorganisms (Lopes et al., 2004). Methanogenic bacteria usually develop in inert conditions, with environmental pH from 6.8 to 7.2. Another study shows that acidity affects the microorganism life with the optimal amount at 6.8 to 7.8. Meanwhile, according to Ezeonu et al., (2006) optimal temperature for anaerobic digestion process is 30-40ºC (mesophilic) and 50-60ºC (thermophilic).

2.5. Composition and Property of biogas

Biogas is a mixture of colourless, flammable gases produced by anaerobic degradation/fermentation of organic waste materials by microbes (Eyo, 2013). It is a flammable gas consisting of methane (54% - 70%), carbon (IV) Oxide (27% - 45%), Nitrogen (0.5% - 3%), Carbon (II) Oxide (0.1%), Oxygen (0.1%) and traces of hydrogen sulphide and water vapour. It is generated by the anaerobic biodegradation of any organic waste such as grass, animal excrements, municipal sewage sludge, abattoir waste, paper waste, grain stalks, water weeds (water hyacinth, algae, duck weed, water lettuce etc.) (Fadairo and Fagbenle, 2014). Biogas consists primarily of methane and carbon dioxide and the composition varies depending upon the anaerobic digestion process utilized (Ehiri et al., 2014).

Biogas is used as an ecologically friendly and future oriented technology in many Countries. The calorific value of biogas is about 6 kWh/m^3 ; this corresponds to about half a litre of Diesel oil. The net calorific value depends on the efficiency of the burners or appliances. Methane is the valuable component under the aspect of using biogas as a fuel.

Table 2.2 General features of biogas (Kigozi et al., 2014).

Energy Content	6-6.5 kWh/m^3
Fuel Equivalent	0.6 - 0.65 l oil/m^3 biogas
Explosion Limits	6 - 12 % biogas in air
Ignition Temperature	650 – 750^{O}C
Critical Pressure	75 - 89 bar
Critical temperature	82.5^{O}C
Normal Density	1.2 kg/m^3
Smell	Bad eggs

2.6. Importance of Biogas Technology

Economic production of biogas can be economically achieved for both large and small scale applications. Hence it can be designed to fit into rural, urban as well as regional and nationwide energy needs (Kigozi et al., 2014). Biogas technology has succeeded in generating a stable energy source that can be used for direct combination in cooking or lighting or indirectly to fuel combustion engines for delivery of electrical power**.** Well-functioning biogas systems can yield a whole range of benefits for their users, the society and the environment in general (Eyo, 2013):production of energy (heat, light, electricity) ;Reduction of workload, mainly for women, in firewood collection and cooking. Environmental advantages through protection of soil, water, air and woody vegetation; macro-economic benefits through decentralized energy generation, import substitution and environmental protection

A process having the potential for waste sterilization/ improvement of hygienic conditions which can inhibit pathogenic action and thus reduce public health hazards from faecal pathogens as well as inhibit pathogens (usually found in high concentration in manure)

The various products of a biogas plant such as methane, carbon dioxide and hydrogen can be used in the production of many industrial chemicals; methane is used in the production of methanol an industrial alcohol used in the making of methylated spirit. The chlorination of methane through photo-catalysis yield chloroform and carbon tetrachloride. Carbon tetrachloride is used in dry cleaning and in fire extinguishers. Carbon dioxide is used in the manufacture of ammonium sulphate from powdered anhydrite it can also be used in the production of urea

2.7. Type of bioreactors

The reactor is the place where any substrate is digested. The classification of reactors is based on the mixing of fluid (substrate and sludge) in the reactor (Balasubramaniyam et al., 2008). These are the completely stirred, non-stirred and batch reactor. In addition to these reactors many combinations of these reactors and additions are available. There are various types of systems; concerning the feed method, mainly two different forms can be distinguished:

- Batch plants
- Continuous plants
  - ✓ CSTR (Continous mixed tank reactor system)
  - ✓ Plug flow
  - ✓ Fed batch (accumulation) system

2.8. Factor affecting biogas production

a. Temperature and Pressure

Temperature for fermentation will greatly effect biogas production. Depending on prevailing conditions methane can be produced within a fairly wide range of temperature. The process of anaerobic fermentation and methane forming bacteria works best in the temperature between 29°C to 41°C or between 49°C to 60°C and pressure of about 1.1 to 1.2 bars absolute (Kaparaju et al., 2008). This is due to fact that two different types of bacteria multiply best in these two different ranges, but the high temperature bacteria are much more sensitive to ambient influences. The rate of gas production increases with the increase in temperature but the percentage of methane reduces. It is found that temperatures between 32^{O}C - 35^{O}C are most efficient for stable and continuous production of methane. Biogas produced outside this range will have a higher percentage of carbon dioxide and other gases than within this range (Ard and akol, 2008).

b. Solid Concentration and Loading Rate:

The cow dung, water and various organic residues from agricultural waste are supplied as feed to the digester. The proportions recommended are: Cow dung to solid waste 1:1 by weight and forming to about 10% of solid content and 90% of water (Elijah et al., 2009). The under loading and overloading reduces the biogas production. The loading of feed must be carried out every day at the same time as to keep the solid concentration ratio constant in the digester.

In general, materials with high volatile-matter content produce more biogas if digested properly (Lehtomaki et al., 2007). The same author reported that the potential danger of a rapid increase in the organic loading would be that the hydrolysis and acidogenic bacteria would produce intermediary products rapidly. Since the multiplication time of methanogenic bacteria is slower, they would not be able to consume the fatty acids at the same rate. The accumulation of fatty acids will lead to a pH drop and hampering the activity of methanogenic bacteria, causing a system failure .

c. Retention Period

It represents the time period for which the fermentable material remains inside the digester. This period ranges from 35 days to 50 days depending upon the climatic conditions and location of the digester. The longer retention period needs larger size digester and it allows more complete digestion of feed (Kaparaju et al., 2008). Under optimum condition 80-90% of total gas production is obtained within a period of 3-4 weeks. Size of the fermentation tank also decides the reaction period.

d. pH Value or Hydrogen Ion Concentration

pH value indicates the degree of acidity or alkalinity of a solution. The pH value is represented as the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalent per litre of solution. The micro-organisms require a neutral or mildly alkaline environment; a too acidic or too alkaline environment will be detrimental since methane formers are sensitive to acidity. Ideal pH value is between7.0 - 8.0 but can go up or down by a further 0.5 (Stefan and Kozani, 2014). The pH value depends on the ratio of acidity and alkalinity and the carbon dioxide content in the digester.

e. Nutrients Concentration:

The major nutrients required by the bacteria in the digester are N_2, P, S, C, H_2, and O_2 to accelerate the anaerobic digestion rate (Ard, and akol, 2008). Thus it is necessary that the major nutrients are supplied in correct chemical form and concentrations. The carbon in carbohydrates supplies the energy and the nitrogen in proteins is needed for building of growth of bacteria. The bacteria responsible for the anaerobic process require both elements nitrogen and carbon, as do all living organisms, but they consume carbon roughly 30 times faster than nitrogen. Assuming all other conditions are favourable for biogas production, a carbon-nitrogen ration of about 30:1 is ideal for the raw materials fed into a biogas plant with 2% phosphorous for maximum biological activity. Too much nitrogen will cause to be left over at the end of digestion (which stops when the carbon has been consumed) and reduce the quality of the fertilizer produced by the biogas plant. The correct ratio of carbon to nitrogen will prevent loss of either fertilizer quality or methane content (Gelegenis et al., 2007).

f. Harmful/inhibitory Materials

The micro-organisms that help to produce biogas are easily affected by many harmful materials. The presence of ammonia, detergents, heavy metals are considered as harmful substance to micro-organisms since their presence reduces the fermentation rate. Also the digested slurry if allowed to remains in digester beyond certain time, it becomes toxic to micro-organism growth (Elijah et al., 2009).

A material may be considered inhibitory when it causes an adverse alteration in the microbial community or inhibition of the bacterial growth. Inhibition is usually revealed by a decrease in methane production and an accumulation of volatile fatty acids. Considerable variations in the inhibition/toxicity levels of some substances (e.g., ammonia, certain light metal ions such as Na, K, Mg, Ca, and Al, heavy metals at high concentrations, chlorophenols, halogenated aliphatics, N-substituted aromatics including nitrobenzenes, nitrophenols, aromatic amines, long-chain fatty acids including lauric and oleic acid, and lignin related compound such as hydroxylmethylfurfural and others) have been reported in the literature (Itodo et al., 1998).

Table 2.3 Toxic materials maximum limitation in a biogas digester (Itodo et al., 1998)

Harmful Materials	Concentration
Sulphate (SO4)	5000 parts per million
Sodium chloride (NaCl)	40,000 parts per million
Copper (Cu)	100 mg per liter
Chromium (Cr)	200 mg per liter
Nickel (Ni)	200-500 mg per liter
Cyanide (CN)	below 25 mg per liter
ABS(detergent compound)	20-40 parts per million
Ammonia (NH3)	1,500-3,000 mg per liter
Sodium (Na)	3,500-5,500 mg per liter
Potassium (K)	2,500-4,500 mg per liter
Calcium (Ca)	2,500-4,500 mg per liter
Magnesium (Mg)	1,000-1,500 mg per liter

Heavy metals also exert some important roles in biochemical reactions (such as the aerobic and anaerobic digestion processes of biomass) being essential to the growth and development of microorganisms, plant and animals. Heavy metals can be stimulatory, inhibitory, or even toxic in biochemical reactions depending on their concentrations. This is mostly due to the chemical binding of heavy metals to the enzymes and microorganisms, resulting in the disruption of enzyme structure and activities (Mudhoo and Kumar, 2013).

Most of these studies tended to examine the effect on the overall performance rather than on the individual stages, i.e., acidogenesis and methanogenesis. Results have shown that the severity of metal inhibition depends upon factors like metal concentration in a soluble, ionic form in the solution, type of metal species, and amount and distribution of biomass in the digester.

Many factors, including substrate concentration, hydraulic retention time (HRT), temperature, pH, and process configuration, affect the performance of the acidogenesis phase. In addition, Mudhoo and Kumar (2013) found that Cd and Cu were the most and Pb and Ni were the least toxic heavy metals to VFA-degrading organisms. Yue and Fang (2001) found that heavy metals inhibited the methanogenic activity of anaerobic starch-degrading granules in the order Zn>Ni>Cu>Cr>Cd. Heavy metals like copper, nickel, zinc, cadmium, chromium and lead have been overwhelmingly reported to be inhibitory and under certain conditions toxic in biochemical reactions depending on their concentrations.

g. Water Content

This should be about 90% of the weight of the total contents. With too much water the rate of production per unit volume in the pit will fall, preventing optimum use of the digester. If the water content is too low, acetic acid will accumulate, inhibiting the fermentation process and hence production and also thick scum will be formed on the surface. The water content differs according to the raw material used for fermentation (Sadaka and Engler, 2003)

h. Total solids

Mattocks (1984) pointed that the percentage of total solid should be between 5% and 12% while other source reported that the best biogas production occur when total solid is ranged from 7% to 10% because of avoiding solids settling down or impeding the flow of gas formed at the lower part of digester. Therefore; dilution of organic substrate or wastes with water to achieve the desirable total solids percentage is required.

i. Stirring or Agitation of the Content of Digester:

Some method of stirring the slurry in a digester is always advantageous, not essential. If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of biogas. This problem is much greater with vegetable waste than with manure, which will tend to remain in suspension and have better contact with the bacteria as a result (Boe et al., 2009).

j. Seeding

To start up a new anaerobic process, it is critical to use inoculums of microorganisms to commence the fermentation process. The common seeding materials include digested sludge from a running biogas plant or material from sewage. Mudhoo and Kumar (2013)indicate that digested sludge is the best inoculum source for anaerobic thermophilic digestion of the treatment of organic fraction of municipal solid waste at dry conditions (30% TS)

k. Particle size

The production of biogas is also affected by particle size of the substrate. Too big particle size is problematic for microbes to digest and it can also result in blockage in the digester, whereas small particle size gives a large surface area for substrate adsorption and thus allows the increased microbial activity followed by increase in the production of gas, 0.5 mm diameter particle size is an optimal for anaerobic digestion process (Braun et al, 1981).

l. C/N ratio

Microorganisms need both nitrogen and carbon for assimilation into their cell structures. Various experiments have shown that the metabolic activity of methanogenic bacteria can be optimized at a C/N ratio of approximately 8-20, whereby the optimum point varies from case to case, depending on the nature of the substrate (Teri, 1994).

m. Gas Collection

The biogas in an anaerobic digester is collected in an inverted drum. The walls of the drum extend down into the slurry to provide a seal. The drum is free to move to accommodate more or less gas as needed. The weight of the drum provides the pressure on the gas system to create flow. The biogas flows through a small hole in the roof of the drum. A non-return valve here is a valuable investment to prevent air being drawn into the digester, which would destroy the activity of the bacteria and provide a potentially explosive mixture inside the drum (Anonymous, 1981).

2.9. Biogas production trends

Biogas is a renewable source of energy, whose consumption amounts to 19% (at 2011) of global energy consumption. The largest renewable energy consumption is given by the traditional biomass (9.3% of the total consumption of renewable energy), while the share of biofuels in the energy market is still limited to 0.8%. The global market of biofuels, which produced about 62 Mtoe y $^{-1}$ in 2011 (Gelegenis et al., 2007) is notoriously dominated by bioethanol and biodiesel.

Ard and akol (2008) found that capturing biogas during waste decomposition and using it for energy (herein call the “biogas digestion” process) can reduce the use of fuel-wood energy, and hence lessens the degradation of local forests. This commensurately reduces the greenhouse gas (GHG) emissions into the air and improves carbon sequestration potential. Each year some 590-880 million tons of methane are released worldwide into the atmosphere through microbial activity. About 90% of the emitted methane derives from biogenic sources, i.e. from the decomposition of biomass. The remainder is of fossil origin (e.g. petrochemical processes). In the northern hemisphere, the present tropospheric methane concentration amounts to about 1.65 ppm (Werner K. 2012).

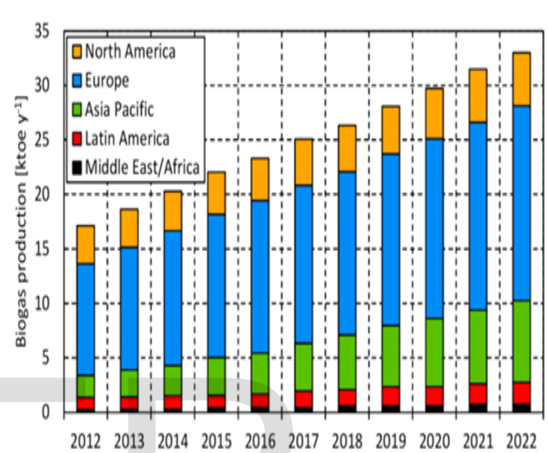


Figure 2.2 biogas production trends from 2012 to 2022 in different areas of the world (Gelegenis et al., 2007).

Internationally the use of biogas as an energy source is not new. The Chinese have been using biogas from agricultural and household waste for cooking since 1929 (Zhong C., 2005).

Germany is one of the more prolific and successful implementers of biogas to power projects. Approximately 13% of all renewable power generated in Germany can be attributed to medium to large scale biogas plants. According to the German Biogas Association there were an estimated 7320 electricity producing biogas plants throughout Germany in 2011 with predicted growth to 7874 in 2013 (Brand, and Richard, 2015).

While not as common as in Europe and Asia, domestic biogas digesters have been installed in South Africa and Kenya since the 1950s. The most widely used biogas model is that of household biogas digester using household and domestic animal waste. Most African countries show a low level of technology development with South Africa listed as having a high level (Heather Griffiths, 2013).

Biogas technology was introduced in Ethiopia as early as 1979. The Ethiopian government decided to subsidize bio-digesters in rural farm households, in an effort to provide a substitute for firewood, charcoal, dried animal dung, and other materials. The National Biogas Program (NBP) was implemented to test the feasibility of biogas in actual farm settings. During the program's first phase, the government disseminated 14,000 bio-digesters across four regional states, Oromia, Amhara, Southern Nations, Nationalities and Peoples and Tigray (Berhe et al., 2017).

2.10. Feed stocks for the production of biogas

Biogas is a clean and environment friendly fuel produced through the anaerobic digestion of organic wastes such as: cow-dung, vegetable wastes, municipal solid waste and industrial wastewater (Njogu et al., 2015). It is increasingly becoming important in domestic and industry as fuel due to its costs and cleanliness. It is generated by the anaerobic biodegradation of any organic waste such as grass, animal excrements, municipal sewage sludge, abattoir waste, paper waste, grain stalks, water weeds (water hyacinth, algae, duck weed, water lettuce etc.) (Fadairo and Fagbenle, 2014). Njogu et al. (2015) also found that Water hyacinth can be used as a potential feedstock for biogas production due to its abundance and high carbon-nitrogen ratio.

2.10.1. Water Hyacinth (Eichhornia crassipes)

Water hyacinth (Eichhornia crassipes Martius) is a monocotyledonous freshwater aquatic plant, belonging to the family Pontederiaceae, related to the lily family (Liliaceae) and is a native of Brazil and Ecuador region. It is also a well-known ornamental plants found in water gardens and aquariums, bears beautiful blue to lilac colored flowers along with their round to oblong curved leaves and waxy coated petioles. It grows from a few inches to about a meter in height. The stem and leaves contain air filled sacs, which help them to stay afloat in water (Anjanabha et al., (2010)).

Water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant additionally can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years (Sullivan et al., 2012). Some water hyacinths were found to grow between 2 and 5 metres a day in some sites in Southeast Asia (Julien et al., 1998). The common water hyacinths (Eichhornia crassipes) are vigorous growers known to double their population in two weeks.

In USA the water hyacinth was introduced in 1884 at the World's Fair in New Orleans, also known as the World Cotton Centennial (Willoughby et al., 1993).

Where as in Africa, the plant was introduced by Belgian colonists to Rwanda for beautify their holdings. It then advanced by natural means to Lake Victoria where it was first sighted in 1988 (Rezene F., 2005). There, without any natural enemies, it has become an ecological plague, suffocating the lake, diminishing the fish reservoir, and hurting the local economies.

The water hyacinth has also appeared in Ethiopia, where it was first reported in 1965 at the Koka Reservoir and in the Awash River, where the Ethiopian Electric Light and Power Authority has managed to bring it under moderate control at considerable cost of human labor. Other infestations in Ethiopia include many bodies of water in the Gambela Region, the Blue Nile from Lake Tana into Sudan, and Lake Ellen near Alem Tena (Thilo and Spiegel, 2008)

Water hyacinth has a multitude of direct and indirect effects on almost all aspects of human life once a water body on which man so much depends is invaded and covered by the weed mats: fisheries; water supply; hydroelectric power generation; human health; agriculture; transport; biodiversity; evapotranspiration and increased cost of water treatment are some of the adverse effects (Makkhanu 1997), However Eichhornia crassipes is an excellent source of biomass, one hectare of standing crop thus produces more than 70,000 m^3 of biogas. one kg of dry matter can yield 370 liters of biogas, giving a heating value of 22,000 kJ/m^3(580 Btu/ft^3) compared to pure methane (895 Btu/ft) (James A. and Duke), that can produce thousands of seeds each year, according to Anjanabha B. et al., (2010) the common water hyacinth (Eichhornia crassipes) are vigorous growers known to double their population in two weeks.

Table 2.4 Average biomass composition of water hyacinth (Anjanabha et al., 2010)

No	Components	% composition
1.	Lignin	10
2.	Cellulose	25
3.	Hemicellulose	35
4.	Ash	20
5.	Nitrogen	03

2.10.2. Cow dung/manures

In the absence of appropriate disposal method cow dung can cause a diverse environmental and health problem such as pathogenic contamination, odor, Greenhouse gas (Harikishan et al., 2003), also in regard to animal wastes, it is important to note pathogens destruction.

Manure can contain numerous pathogenic organisms that are associated with human diseases including Salmonella, Escherichia coli, Giardia, Campylobacter, and Cryptosporidium (Klein et al., 2010).

2.10.3. Inoculum

The rumen fluid from animal gut is one of the inoculum with many types of bacterial population. The rumen community is dominated by Bacteroidetes (54%), Fibrobacteres (12%), Firmicutes (10%), and Lentisphaerae (8%). Only 1.4% of the sequence reads could not be assigned to any bacterial phylum (unclassified bacteria). The remaining sequences were assigned to minor phyla, mainly Proteobacteria (4%), Tenericutes (4%), and candidate phylum SR1 (2%) (Rabiu et al., 2014).

2.12. Chemical composition and its property of water hyacinth

Water hyacinth grows at a very rapid pace and contains very high nitrogen content. The mixture of cow dung and water hyacinth slurry has proven to produce more biogas than when used alone (McCann et al., 1996). The left-over slurry or sludge can be transported as liquid fertilizer. They can practically grow in any habitat and requires little to no maintenance, but they prefer to grow in warm climate. Further, they can be used to purify water bodies containing high amounts of heavy metal contamination (Kivais and Mtila, 2005).

Water hyacinth comprises 95 percent water and only 5 percent dry matter of which 50 per cent is silica, 30 per cent potassium, 15 per cent nitrogen and 5 per cent protein. From the unique chemical content of the water hyacinth, its beneficial uses are limited (Langeland et al., 2008). The water hyacinth cannot be used as a livestock feed because it contains too much silica, calcium oxalate, potassium and too little protein. It cannot be directly used as a fertilizer because it's C: N ratio is too high necessitating addition of N-fertilizer.

A few beneficial uses have been identified but the large scale production is uneconomical when compared with the negative effects attributed to the water hyacinth field. Such beneficial uses include biogas production and removal of heavy metals from industrial pollution (Sridhar et al., 2014).

Table 2.5 Chemical composition of substrates (Sridhar et al., 2014)

Parameter	Cow Dung	Water Hyacinth
Organic carbon, mg/Kg	190.715±.021	300.0±.01
Total Kjeldahl Nitrogen, mg/Kg	20.045±.007	10.44±.01
Total Phosphorus, mg/Kg	30.800±.014	10.92±.01
Potassium, K, mg/Kg	70.335±.007	70.27±.02
Mn (mg/kg)	-	234.65±.07
Zn (mg/kg)	7.085±.007	45.70±.14
Fe (mg/kg)	-	76.30±.00
Pb (mg/kg)	12.150±.071	0.48±.02
Cu (mg/kg)	0.420±.014	11.57±.01
Cr (mg/kg)	-	23.74±.01
Cd (mg/kg)	1.185±.007	0.05±.01
Ni (mg/kg)	12.850±.071	46.85±.07

2.12. Water Hyacinth in Lake Tana

Lake Tana is the largest Lake in Ethiopia which accounts for 50% of the fresh water resource of the country. The Lake has a surface area of 3111 km^2, 284 km^3 volume, and has maximum length of 90 km and width of 65 km. Lake Tana is a shallow lake with a maximum depth of 14 m (m), but the average depth is eight m. This lake is the source of the Abay (Blue Nile) River and covers 20% of the surface area of the Lake Tana sub-basin (Goshu and Aynalem, 2017).

It is a multi-use water body where many millions of people in the region depend on its ecological and socio-economical values. The basin in its natural state has high potential for agriculture, livestock, water resource, forest and wildlife, tourism, and fishery development besides too high biological diversity. There are animals, plants, fish, wetland and forest resources. The basin has also fertile soil and cultivable land for intensive agriculture. The agro-ecologies are also suitable to produce more than once per year.

However, this multi-purpose lake is facing multi-problems. Recently, water hyacinth, one of the most ecologically dangerous weed infestations has been attacked the shore areas of this sensitive lake.

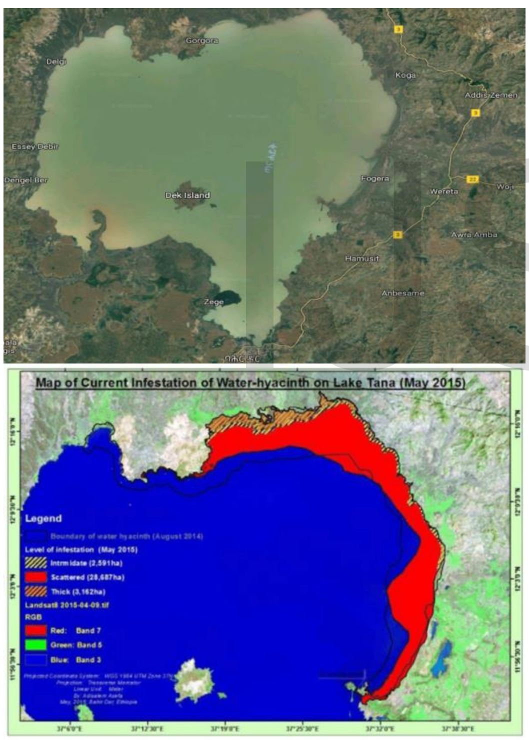


Figure 2.3 the Water Hyacint infestation in Lake Tana (Goshu G. and Aynalem S. 2017)

Goshu and Aynalem (2017) stated that in september 2011, it was officially recognized that water hyacinth (Eichhornia crassipes), infested Lake Tana. According to the 2012 survey, about 20 ha of the shore on the north-eastern part of Lake Tana was infested. Following this infestation, Bureau of Environmental Protection, Land Administration and Use (BoEPLAU) made a physical removal campaign. In 2014 estimated water hyacinth coverage was nearly 40, 000 ha shore area of the lake (Wassie A. 2014).

Figure 2.4 Water Hyacinth movement in Lake Tana from one part to the other by wave

2.13. Impacts of water hyacinth

Water hyacinth affects the Lake population in many negative ways. Once the water body is covered by the water hyacinth fishing activities will be curtailed as landing sites would be inaccessible. Furthermore breeding sites will be reduced and fishermen take longer to reach fishing grounds. Also, evapotranspiration is increased as loss of biodiversity in the water body covered by the water hyacinth (Willoughby et al., 1993).

Water hyacinth also interferes with water treatment, irrigation, and smothers aquatic life by deoxygenating the water (Makkhanu 1997).

The cost of purifying water tainted by water hyacinth will be increased tremendously. Hydroelectric power production will be affected since turbines would be clogged resulting into expensive repair, overhaul and maintenance. Human health will be affected in many ways: shoreline mats are habitats for certain snails (schisostomia vectors) and mosquitoes which spread malaria (Langeland et al. 2008).

2.14. Water hyacinth controlling mechanism

The three commonly used control methods against water hyacinth infestations are physical, chemical, and biological controls (Schmitz et al., 1993). No one control method is generally better than the others, because each has its advantages and disadvantages. The optimum control depends on the specific conditions of each affected location such as the extent of water hyacinth infestation, regional climate, and proximity to human and wildlife (Sullivan et al., 2008).

a. Physical

Physical methods for control of water hyacinth involve drainage of the water body, manual removal of the weeds or pulling through nets (Malik and Anushree 2007). Employing machines like weed harvesters, crusher boats, and destruction boats prove expensive, the costs of water hyacinth management in China were estimated to amount around EUR 1 billion annually (Njogu et al., 2015). In Europe, management costs to remove 200,000 tonnes of the plant along 75 km in the Guadiana river basin on the Portuguese-Spanish border amounted to EUR 14,680,000 between 2005 and 2008.

b. Chemical

A generally cheaper method has been used worldwide to reduce water hyacinth populations through the use of chemical herbicides (such as Paraquat, Diquat, Glyphosate, Amitrole, 2, 4-D acid) (Jimenez and Maricela 2014). However, their use directly interferes with the bio control agents currently deployed against this weed. Long term use may degrade water quality and put aquatic life at risk (Villamagna et al., 2009) with significant socioeconomic impacts if beneficial or designated uses of the water body such as drinking and preparing food are affected.

c. Biological

In recent years, focus has shifted to natural enemies of water hyacinth including plant pathogens (Malik and Anushree 2007). The aim of any biological control is not to eradicate the weed, but to reduce its abundance to a level where it is no longer problematic. While there exists several native enemies of water hyacinth, two South American weevil beetles (Neochetina eichhorniae and Neochetina bruchi) and two water hyacinth moth species (Niphograpta albiguttalis and Xubida infusella) have had effective long-term control of water hyacinth in many countries (Julien et al., 1998).

d. Reduction by utilization

Research into the utilization and related technologies for the control of water hyacinth have been tested over the last few decades (Kivais and Mtila, 2005). It is being speculated that the biomass can be used in waste water treatment, heavy metal and dye remediation, as substrate for bioethanol and biogas production, industrial uses, medicines, animal feed, agriculture and sustainable development.

Recent studies have found that this nuisance weed is a very good source of renewable energy for the biosynthesis of biofuel. Since the plant has abundant nitrogen content, it can be used a substrate for biogas production (Pachaiyappan et al., 2015).Eichhornia crassipes can potentially be a resource due to its carbohydrate content (18% of cellulose, 50% of hemicellulose) (Njogu et al., 2015). It can be used as a potential feedstock for biogas production due to its abundance and high carbon-nitrogen ratio.

2.15. Biogas production from water hyacinth (Eichhornia crassipes) trend

In Kenya the weed has invaded Lake Victoria and poses great socioeconomic and environmental challenges. Weed were harvested from the Lake and left in the open to rot and decay leading to loss of aesthetics, land and air pollution.

However, Njogu et al., (2015) works sample from Lake Victoria pulped and blend with cow dung at a ratio of 3:1 as inoculum. The mixture was mixed with water at a ratio of 1:1 and fed into a 6 m^3 digester. The temperature ranged between 22.8^{O}C - 36.6^{O}C and pH 7.4 - 8.5. Biogas was found to contain 49% - 53% methane (CH_4), 30% - 33% carbon dioxide (CO_2), 5% - 6% nitrogen (N_2) and traces of hydrogen sulphide (H_2S).

In Nigeria, identified feedstock substrate for an economically feasible biogas production includes water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage. Co-digestion of water hyacinth with cow dung increased biogas yield by 47% (75% cow dung), 25% (50% cow dung) and 20% (25% cow dung) over water hyacinth alone (Sudhakar et al., 2013).

Water hyacinth: cow dung proportions on dry weight basis aimed at investigating the efficiency of the mixture in biogas production. The four proportions of water hyacinth: cow dung on a weight percentage basis were: A = 75:25; B= 50:50; C = 25:75 and D = 100:0; the proportion of total solid to water was same in all the fermentation slurry samples; 2.25m^3 of water to 180kg of solids.

The optimum amount of rumen fluid that produced high level of biogas is in the range of 25 - 50% (Rabiu et al., 2014). Similarly, Forster et al., (2008) reported the best performance of biodegradation for food waste and methane generation is when 20 - 30% of inoculums was used in the bio-digester.

3. MATERIALS AND METHODS

3.1. Description of the study area

The study area is Lake Tana which is found in Amhara National Regional State in the north-western Ethiopian highlands, from Bahirdar along to Gondar city 563km far from Addis Ababa city. The lake is approximately 84 kilometers long and 66 kilometers wide, with average depth of 9 meters, and an elevation of 1,788 meters (Goshu G. and Aynalem S. 2017). The experiment was conducted in Biotechnology and Environmental Engineering Laboratory of College of Biological and Chemical Engineering at Addis Ababa Science and Technology University which is located at a latitude of 9°1′48′′ N, longitude of 38°44′24′′E and an altitude of 2,355 m.a.s.l (Google earth,2018).

3.2. Experimental materials and chemicals

The major raw material used for biogas production during the experimental work was water hyacinth (Eichhornia crassipes) and Cow dung inoculated by Rumen fluid, Analytical grade reagent chemicals were used 10N NaOH, 1%H2SO4 and Distilled Water

3.3. Experimental equipment's

The equipment used during the experimental works were Atomic Absorption Spectrophotometer, (AAS Series AA), portable gas analyser (PG300 series), magnetic stirrer, burette, dropper, pH meter, digital mass balance, oven, muffle furnace (BST/MF/3000 model), refractometry (PCE-010 series), Autoclave (3870 HSG D- line model), different size conical and Erlenmeyer flasks, beakers, measuring cylinders, plate counter SC6+and whatman number 1filter paper.

The experimental work began in December, 2017 and ended in May, 2018; a total of six months were spent for the laboratory works. Heavy metal and total nitrogen content analysis was done at Bless Agri Food laboratory service; in east side of Addis Ababa (Lege Tafo) and lignin, hemicellulose and cellulose analysis was conducted at Ethiopian Environmental and Forest research Institute Laboratory (Addis Ababa), biogas composition, reducing sugar content, moisture content, total solid ,fixed/total organic carbon content and volatile solid/ash content was conducted at Addis Ababa Science and Technology University Chemical Engineering laboratory. Microorganism counting, autoclave and all others not mentioned were done in Biotechnology Laboratory; for all laboratory analysis water hyacinth (Eichhornia crassipes) sample was collected from Lake Tana.

3.4. Experimental methods

3.4.1. Feedstock and inoculum

For this research two types of substrates; Water hyacinth (Eichhornia crassipes) and fresh Cow manure were used as feedstock for anaerobic digestion. Water hyacinth were collected from five different assigned area of the Lake at Gorgora, Makisegnit, Enfiranz, Tana kirkos and at the exit of abay river whereas, cow dung and rumen fluid (inoculum) were obtained from Addis Ababa abattoir enterprise. After collection, cow dung and rumen fluid (inoculum) were kept in a refrigerator at 4OC until use. To facilitate anaerobic digestion, rumen fluid was used as inoculums. All feed feedstock was transported via vehicle transportation after well packed in High density poly ethylene poly bag and inoculum was by Polyethylene terephthalate bottle.

For this, fresh rumen was filtered through a cloth of 0.5 mm sieve diameter to separate solid content from slurry. Prior to use, the inoculum was starved for 1 week by incubating at 38 ºC to remove the easily degradable VS present in inoculums.

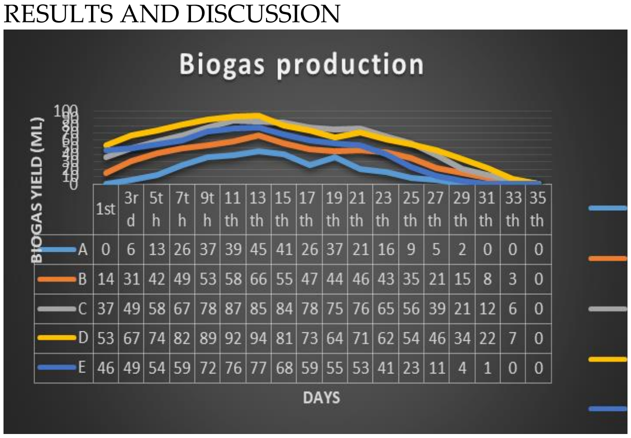
3.4.2. Design of the Experiment

This study consisted of anaerobic Co-digestion of Water Hyacinth (in dry basis) with cow dung. The two substrates were mixed in different combinations ranged from 0% to 100% of each other with varied parameters of Temperature ranged from 30OC - 40OC, pH from 6.8 - 7.8 pH reading and Rumen fluid ranged from 5% - 50% of the total volume used and randomly distributed the combination in each of the sample triplicated by design expert 6.0.8 software before Anaerobic Digestion. Bio-digester A stands for 100%WH, B: stands for 75%WH + 25%CD, C: 50%WH + 50CD, D: 25%WH +75%CD and E: for 100%CD alone. Biogas production is accomplished by installing 1L wash bottle with 700ml sample volume and connecting and tightening by PVC glue with glucose bag gas collector. The daily biogas produced was measured by immersing in 5 L volume beaker by water displacement method.

3.5. Sample preparation

Fresh water hyacinth was collected from five different selected area of Lake Tana in November 2017. It was washed with running tap water. Then it was dried in sunlight for 5 days at approximate daily temperature of 25OC and milled into powder and then sieved through a sieve analysis apparatus of 0.5 mm sieve diameter to separate larger particle content from the fine sample. The dried and sieved water hyacinth sample was stored in room temperature until further use.

RESULTS AND DISCUSSION



	1st	3rd	5th	7th	9th	11th	13th	15th	17th	19th	21th	23th	25th	27th	29th	31th	33th	35th
A	0	6	13	26	37	39	45	41	26	37	21	16	9	5	2	0	0	0
B	14	31	42	49	53	58	66	55	47	44	46	43	35	21	15	8	3	0
C	37	49	58	67	78	87	85	84	78	75	76	65	56	39	21	12	6	0
D	53	67	74	82	89	92	94	81	73	64	71	62	54	46	34	22	7	0
E	46	49	54	59	72	76	77	68	59	55	53	41	23	11	4	1	0	0

Table 4.1 biogas production result (in each 3rd day record)

All bio-digester appeared to yield more biogas than WH alone. This might be due to the microorganism less capability of degrading pure water hyacinth substrate than CD to serve as a source of energy for growth and respiration, however the addition of cow dung increase a better yield from WH substrate. Thus, biogas production was a function of the feedstock's organic content and its biodegradability potential for biogas production, since Volatile solid/TOC from TS content of the water hyacinth substrate was 86.17%; which is greater than CD with 84.34%. This shows that a large fraction of the Water hyacinth was biodegradable than cow dung. Biogas production ended fast in 100% of WH and in this experiment, it appeared that microorganism was finished too fast degradable substance in case of WH alone compared to the rest of digester whereas in CD alone it might be microorganisms was easily degraded the available nutrients in short period of time.

Lastly obtaining the final volume of produced biogas using water displacement method , and measuring the product yield for each run, then the higher produced biogas volume were give as the optimal condition, So taking this optimal condition which run was, apply it for real design of biogas plant.

After the result founded from the water displacement method of measuring; the highest product yield was obtained the optimum varying parameters, from table 3.1, Run 3 and run 39, which has 1,065ml biogas product yield with 25%WH, 75%CD, pH, 35oC temperature and 27.5% Rumen fluid whereas the lowest biogas product yield was measured in run 1 which has 253ml biogas product yield with 100%WH, 6.8pH, 30oC temperature and 5% Rumen fluid. The experiment was indicates as RF dropped to 5% and pH increased to 8.33 the biogas production significantly affected.

the standard error of the design was relatively lower in the range of water hyacinth substrate from 25 to 50% and cow dung from 50 to 75% proportion and standard error was highest for the water hyacinth substrate ranged from 50 to 100% and cow dung 0 to 50 % ratio, it indicates the best combination with lowest standard error of design was better yield of biogas product which was from

25 to 50% water hyacinth and 50 to 75% cow dung ratio.

4.3.1. Effects of parameters interaction

There are four interaction factors analyzed by design expert, these are:

- AB (Water hyacinth and Cow dung)
- AC (Water hyacinth and pH)
- AD (Water hyacinth and Temperature)
- AE (Water hyacinth and Rumen fluid)

I. AB (Water hyacinth and Cow dung)

The effect of Water hyacinth and Cow dung substrate mixing ratio on biogas product yield is shown in 3D plot of Figure 4.2 As it can be observed from the biogas yield plot, as Water hyacinth substrate increased 0 to 50% the biogas yield also increased and after 50%, it started to decline and too low yield in 100% Water hyacinth, the maximum yield was found in the range of water hyacinth 25 to 50% and cow dung 50 to75% combination ratio. Typically this confirmed to the fact that maximum biogas yield was 25%WH and 75% CD ratio.

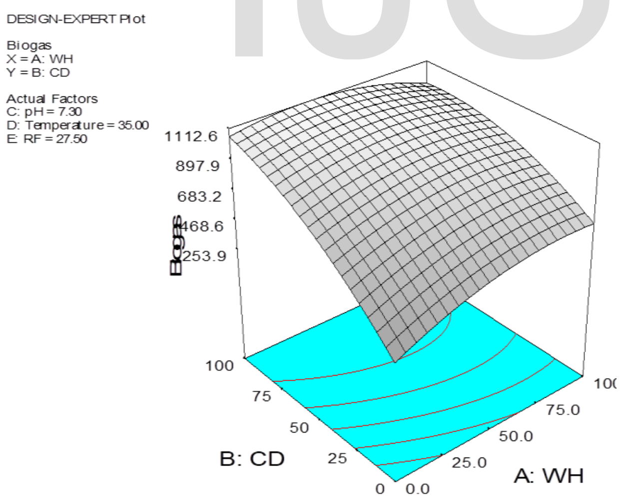


Figure 4.2 3D plot of water hyacinth interaction with cow dung on biogas yield

II. AC (Water hyacinth and pH)

In case of water hyacinth and pH interaction biogas product yield is shown in 3D plot of Figure 4.3. As it can be observed from the biogas yield plot, as pH increased from 6.8 to 7.3pH the water hyacinth biodegradability increased which increased the biogas yield whereas as pH ranged from 7.3 to 7.8 it started a minimal decline on biogas yield, it might be the microorganism activity slightly affected by ammonia production as pH increased. In fact that maximum biogas yield was at 25%WH and 7.3pH value.

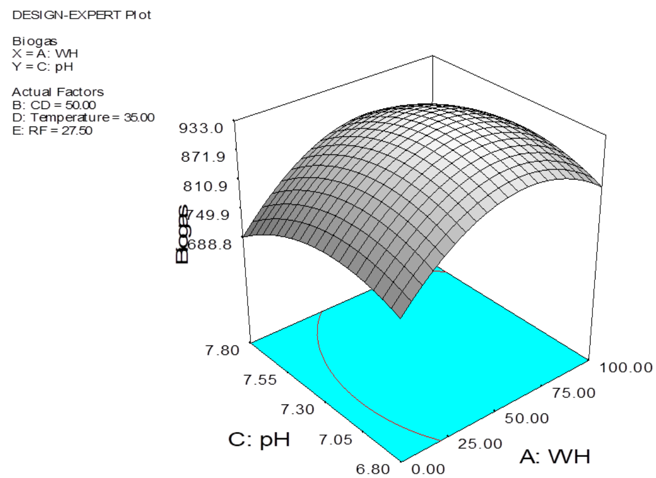


Figure 4.3 3D plot of water hyacinth interaction with pH value on biogas yield

I. AD (Water hyacinth and Temperature)

From figure 4.4 shows that both Water hyacinth and Temperature have strong effect on biogas yield at their mid-level values. At lower level values of both factors and further increment beyond mid values showed a decrease in on biogas yield. The plot indicates that maximum yield occurred at water hyacinth ratio of 25% and Temperature of 35oC.

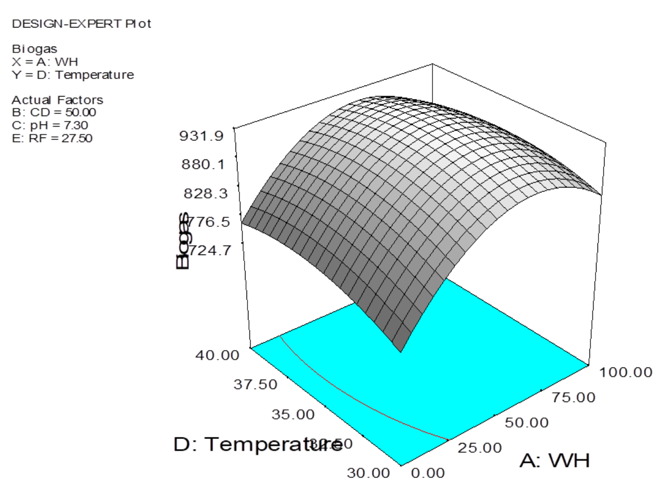


Figure 4.4 3D plot of water hyacinth interaction with Temperature on biogas yield

I. AE (Water hyacinth and Rumen fluid)

In case of water hyacinth and rumen fluid interaction biogas product yield is shown in 3D plot of Figure 4.5 As it can be observed from the biogas yield plot, as rumen fluid volume increased from 5 to 50% generally the biogas yield increased whereas above 50% gradually decline the biogas yield this might be the accumulation volatile fatty acid in fermentation slurry disturbs the microbial activity, since methanogens are highly sensitive to acidity.

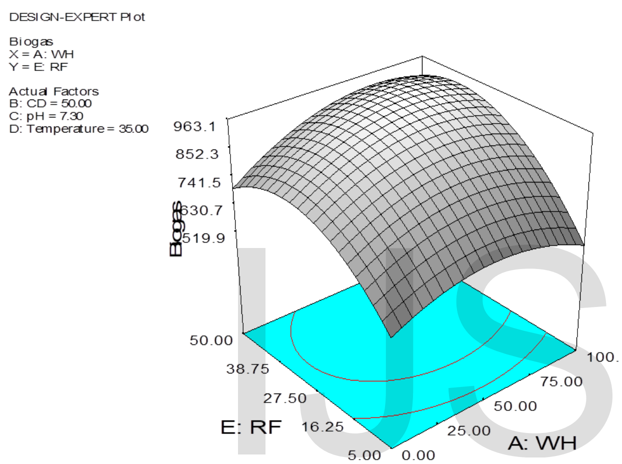


Figure 4.5 3D plot of water hyacinth interaction with rumen fluid on biogas yield

2.3.2. Biogas product composition (gas analyzer)

Lastly obtaining the final composition of methane by using portable gas analyzer instrument and the, the higher percentage were taken as the optimal condition. From digester A: 100%WH there was no methane production observed, but CO_2 was 43%Vol and H_2S 13ppm. This may suggest that there was no contribution of biogas production from water hyacinth alone when incubated under anaerobic condition. In digester B: 75%WH with 25% the methane composition was 4.43%Vol, CO_2 measured 38%Vol and H_2S 7ppm, whereas digester C: 50%WH with 50% the methane composition was 17.47%Vol, CO_2 34%Vol and H_2S 3ppm. Digester D: 25%WH with 75% was relatively a better yield of methane with 22.47%Vol, CO_2 33%Vol and H_2S 1ppm content. In digester E: 100%CD the methane composition was 34%Vol, CO_2 38.5%Vol and H_2S 0.1ppm. It has been already reported that the mixture of cow dung and water hyacinth slurry has proven to produce more biogas than when used water Hyacinth alone. The biogas yield from digester D was higher than digester E; however methane composition was lower than digester E: thus exhibited that methane content was highly dependent by the nature of raw material. In addition co-digestion of organic waste with cow dung has been mentioned in the Works of Sugumaran et al., (2014) no methane production observed from 100% water hyacinth, but 55% of CO2 the maximum methane (24%) was observed in the ratio of 50%WH + 50% CD followed by 25%WH + 75%CD (21.42%) on 30^{th} day and 75% WH+25% CD combination with low methane (8.25%). The difference in biogas composition from other work might the parameters used; since the pH of the digester is a function of the concentration of volatile fatty acids produced, bicarbonate alkalinity of the system, and the amount of carbon dioxide produced. In this study better methane composition was found in digester E of cow dung alone and digester D was the 2^{nd} with 25%WH with 75%CD mixing ratio.

CONCLUSION AND RECOMMENDATION

Conclusion

The number of microorganisms in rumen fluid sample has approximately $92*10^6$ - $11*10^7$ microorganisms, which have enough potential for activating anaerobic digestion process.

From the laboratory result, the Volatile solid content/TOC of the water hyacinth substrate was 86.17% of the TS. This implies that water hyacinth can serve as an important feedstock for biogas production. The lignin content results 3.8%, which is lower value and can be easily biodegraded by Microorganism community the mass components of WH substrate.

The two most biochemical reaction disturbance heavy metals were cadmium (Cd) and Zinc (Zn) metals in acedogenesis and Methanogenesis steps respectively, whereas this study results 7.56 (mg/kg) Zn and <0.1(mg/kg) Cd value, but based on other studies the effect this much heavy metal content are not significant for disturbance of microorganisms biochemical reaction (Yue and Fang, 2001).

Sugar concentration of pre-treated sample results a refractive index value of 1.34061 and 5.23% of sugar content in 100g sample which is an optimum compared to other studies.

From this experiment gas production was noticed from day one of the experiment in most of the bio-digester. However, the bio-digester with 5% rumen fluid and 100% water hyacinth mixing ratio noticed after day three. The highest biogas production was 1,065ml for substrate mix of 25 % WH+75% CD with 7.3 pH, 27.5%RF and 35oC and lowest was 286 for 100% WH with 6.80 pH, 5%RF and 30oC, from these the biogas yield is highly dependent on parameters such that Temperature, pH, Co-digestion ratio and Rumen fluid percentage.

In this study biogas composition; the highest methane content of 34% obtained with 38.5%Vol CO2 and H2S 0.1ppm from 100%CD and the lowest methane content of 0% with 43%Vol and H2S 13ppm from 100%WH. Co-digestion of water hyacinth with cow dung increased Methane yield by 22.47% (75% cow dung), 17.47% (50% cow dung) and 4.43% (25% cow dung) over water hyacinth alone. From the present work it can be conclude that cow dung has been shown to be a potentially useful substrate for better yield of biogas and also highest methane composition.

These experimental studies on production biogas from water hyacinth Co-digestion with Cow dung would be quite useful in developing an appropriate technology for biogas production plant.

Recommendation

Based on the results obtained from the study for future work the following suggestions have been made:-

- This investigation was done at mesophilic temperature (30 - 40oC) but it should be

investigated at Cryophilic: < 200C and at Thermophilic: >450C condition.

- The study indicated that it is possible to produce biogas from a mixture of dried Water

hyacinth co-digestion with Cow dung, However the percentage of methane obtained was lower than the combustible biogas composition, so that it is better to upgrade the purity of methane and Further studies should be investigated on co-digestion with other substrates such as pig manure, food waste and poultry for their yield in biogas production.

- Parameters such as, pH, agitation time interval, Temperature and design of bio-digester should be further studied.

- It's better to work more on concentration of sulphuric acid concentration above 1% to compare the amount of reduced sugar obtained.

- Lastly I recommend to design a conventional biogas bio-digester plant in order to use Water hyacinth as present as in the Lake Tana and when the water hyacinth abundance decreased to replace by other biomass such as grass, animal excrements, municipal sewage sludge, abattoir waste, paper waste and grain stalks.

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Appendices

Plate 1: Sample collection at Lake Tana

Plate 2: the Consequence of WH weeds infestation and farming in Lake Tana area

Plate 3: Rumen fluid collection at Addis Ababa abattoir enterprise and bio-digester design configuration

Plate 4: WH sample before and after acid pre-treatment

Plate 6: Media preparation for MO culturing and plate counting colonies

Plate 7: Measuring of reducing sugar content and biogas composition

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