A MODIFIED DIGESTER PROTOTYPE TO PRODUCE BIOGAS FROM SOME AGRICULTURAL WASTES AS A RENEWABLE ENERGY RESOURCE

Submitted By

SAMIR ADEEB DEMETRY
B. Sc. Engineering, Cairo University, 1981
M.Sc. Environmental Engineering, Ain Shames University 2012
A Thesis Submitted in Partial Fulfillment
Of
The Requirement for the Doctor of Philosophy Degree
In
Environmental Sciences

Department of Engineering Science
Institute of Environmental Studies and Research
Ain Shams University

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Engineer
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Abstract

Anaerobic digestion is a very promising solution for the treatment of agricultural waste, preventing pollution and leading to efficient energy production. Biomass waste including Water hyacinth (WH) and most of the organic wastes and animal manure due to their organic compositions have a great potential for biogas production.

Some Lab-scale experiments were carried on some blends of fresh Cow manure (CM) collected from cow breeding farm and some of Water hyacinth harvested from Nile River. Composition analyses of raw materials were carried out using Wicklly and Black methods and Kjeldal method. These Lab-scale experiments were carried to get the best condition for producing the biogas. By using a feed stock containing 30 g TS/L for 30 days at constant temperatures namely 25°C, 37°C and 45°C were fixed. It was found that the performance at 37°C was much better than the other temperatures. For different C/N ratios namely, CN20, CN25, and CN30, the experiments were conducted in the period of 30 days at temperature 37°C. The results showed that the yield of Biogas in descending order for CN30, CN25 and CN20 respectively.

By charging the mobile digester by some blends of Water hyacinth and Cow manure (100% CM; 75% CM + 25% WH; 50%CM + 50% WH; 25% CM + 75% WH; and 100% WH) biogas was produced as results of treatments (122L, 148L, 176L, 153L, and 171L respectively). The contents of methane gas in biogas were between 50-60%.

Results revealed that bio-organic materials could be potential sources for biogas production. Using a mobile digester will have double advantages. The first is generating biogas on site. Second is disposal of biomass wastes.

Key words: Biogas, Mobile Digester, Co-digestion, Organic wastes, Water hyacinth

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LIST OF ABBREVIATIONS

AD	Anaerobic Digestion
BOD	Biological Oxygen Demand
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand and
C/N	Carbon to Nitrogen ratio
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
GHG	Greenhouse Gases
ODM	Organic Dry Matter
OM	Organic Matter
pH	Hydrogen exponent
TS	Total Solids
VFA	Volatile Fatty Acid
VOC	*Volatile Organic Compound*
VS	Volatile Solids

1. INTRODUCTION

By increasing the fossil fuels dependence and its depletion, in addition to its price rising, so the world searches about another method to getting the energy, which must be safe and cheap. On the other hand there are millions of tons of biomass waste being produced every year for which disposal is a problem. These wastes have a great potential for biogas production owing to its organic composition. At the same time the world is rapidly depleting its supply of natural gas, which is known to be the cleanest of the fossil fuels. Anaerobic digestion (AD) is a highly promising technology for converting biomass waste into methane gas, which may directly be used as an energy source instead of natural gas. If the biogas can be harvested, it could use for generating electricity. It would not only help in reducing greenhouse gas emission and global warming but also help at reducing the requirements of fossil fuels for electricity generation and ensures energy security.

The formation of biogas is a natural phenomenon that naturally occurs in wetland, manure stack, human and animal intestines. For centuries, humans have harvested the power of bacteriological digestion, by recovering naturally formed biogas to use for lighting, cooking, heating or to power mechanical engines. In Asia, millions of family digesters were built to provide cooking fuel and lighting in rural areas. During the Second World War, German army trucks were fueled with biogas collected from farmers manure (gas engine). Over the last 50 years remarkable progress has been made in the development of anaerobic digesters (bioreactors) to increase methane (CH_4) yield and improve its process flow technologies. Nowadays, thousands of projects around the world, from small dairy farms to large municipal waste water treatment plants, are demonstrating that biogas recovery systems are environmentally and economically sound. In Europe, villages are entirely supplied in electricity and heat from their local centralized biogas plants. The Commission recently proposed the Europe 2020 flagship initiative for a resource-efficient Europe and within this framework it is now putting forward a series of long-term policy plans in areas such as transport, energy and climate change. Europe 2020 Strategy for smart, sustainable and inclusive growth includes five headline targets that set out where the EU should be in 2020. One of them relates to climate and energy. Member States have committed themselves to reducing greenhouse gas emissions (GHG) by 20%, increasing the share of renewable energy in the EU's energy mix to 20%, and achieving the 20% energy efficiency target by 2020. According to a study by the Insitut für Energetik und Umwelt in Leipzig, 500 billion cubic meters is the theoretical potential for biogas production in Europe (representing 166 Mtoe of primary energy production compared to 5,9 Mtoe generated from biogas today). Germany, Austria and Denmark produce the largest share of biogas in agricultural plants using energy crops, agricultural by-products and manure, whereas the UK, Italy, France and Spain predominantly use landfill gas.

Infestations of Water hyacinth (WH) are reaching crisis proportions in important freshwater bodies. This is a cause of environmental, economic, and social problems and accumulated damages that can easily be valued in the order of billions of dollars. It poses serious socioeconomic and environmental problems for millions of people in riparian communities and is, therefore, an added constraint on development. Water hyacinths cause ecological and economic problems by impeding navigation and fishing activities, clogging irrigation systems and by creating a chronic shortage of dissolved oxygen harmful to the fauna and the flora **(Seehausen et al., 1997** and

Malik, 2007). It also considered as harbours of poisonous snakes and insects. Water hyacinth is an added constraint on development, where it obstructs electricity generation, irrigation, navigation, and fishing; increases water loss resulting from evapotranspiration. It is a strong reason of proliferation of agents of several deadly diseases provides habitat for vectors of malaria and bilharzia and can host agents of amoebic dysentery and typhoid.

On the other hand by using the waste to produce the biogas it will eliminate the volume of wastes which represent an enemy to the environment. By using the wastes to produced biogas, the cereals which are used at some country to produce biogas will only be used to feed people and animals. So by using some wastes, food crises and its prices increasing could be prevented.

The target of this research is fabricating a digester, as a method to produce safe and cheap energy, from agricultural wastes and animal manure. The subject of this research is creating a complex biogas production and utilization system and waste disposal requirements without transformation of the system. So both the energy and the waste disposal goals can be achieved together so, it is addressing multiple goals. The production and utilization of renewable energy sources are justified not only by energy, political, environmental and competitive aspects, but by rural development aspects as well. AD contributes to socio-economic development by creating jobs in developing areas. Usage of AD allows improving local chains, operation, service and maintenance and it will create new jobs without additional cost the municipality. AD technology helps to reduce odours generated by the aerobic decomposition of manure and other wastes.

The purpose of this thesis aims at designing, fabricating and testing a portable digester to produce a biogas using different substrates of alternative feed stocks. Cow manure (CM) and agriculture weeds like Water hyacinth and some blends of them were used as feed substrates. Using more than one substrate is called co-substrate mixtures (co-digestion).

Some theoretical studies of previous researches and studies related to this subject of research were reviewed. Experimental work was followed to getting biogas from dry fermentation of some agricultural wastes. The experiments were done by selection of some agricultural wastes namely Water hyacinth and cow manure getting different blends from them.

Getting rid of agricultural wastes is very important problem at Egypt. Biogas production from Water hyacinth or other wastes could alleviate energy problems in the remote towns and villages along the banks of the Nile. The production of organic fertilizer which was produced as a by-product from AD has high quality fertilizer for agriculture is added value to dismiss the agriculture weeds and agricultural wastes.

2. REVIEW OF LITERATURE

This chapter presents some of the past studies, which are related to the research points of this thesis and have been reported. In addition, the production of biogas will be discussed. Several studies were available for the potential of WH as a raw material for the production of biogas. Also there are some reports which were deled with co- digestion issue **(Okewale et al., 2016)**.

2.1. Historical background

Historical evidence indicates that biogas was used for heating bath water in Assyria during the10th century BC and in Persia during the16th century BC. Even around 3000 BC the Sumerians practiced the anaerobic cleansing of waste. The Roman scholar Pliny described around 50 BC some glimmering lights appearing underneath the surface of swamps. In 1776 Alexander Volta personally collected biogas from the Lake Como to examine it. His findings showed that the formation of gas depends on a fermentation process and that may form an explosive mixture with air. The English physicist Faraday also performed some experiments with marsh gas and identified hydrocarbons as part of this. Alexander Volta was the first researcher describing the formation of inflammable gases in (low-temperature) marshes and lake sediments scientifically. His letters on the formation of "Aria inflammable nativa delle Paludi" where published in Italy in 1776. The importance of these findings was fully recognised by the scientific community, which is reflected by the fact that his letters were translated into German only two years after their appearance. Around the year1800, Dalton, Henry and Davy first described the chemical structure of methane, however the final chemical structure of methane (CH_4), was firstly elucidated by Avogadro in 1821. In 1804, Dalton gave the correct chemical formula for methane.

The science of AD is as old as scientific research can be and includes the names of world's most famous searchers: Benjamin Franklin described as early as 1764 that he was able to light a large surface of a shallow muddy lake in New Jersey. This experiment was reported in a letter to Joseph Priestly in England who published in 1790 his own experiences with the inflammable air.

The oldest publication of the temperature influence on methane formation was written by Popoff at 1875. He found that river sediments could form biogas at temperatures as low as 6°C. With increasing temperature up to 50°C the gas production was stimulated. He also observed that the composition of the gas formed did not change with temperature.

Louis Pasteur tried in 1884 to produce biogas from, horse dung collected from Paris roads. The application of energy from renewable resources started from this time on. The volume of gas collected at 35°C was so great that Louis Pasteur concluded anaerobic manure fermentation might supply gas for heating and illumination under special circumstances. But the proposal, made in jest by the newspaper "*Le Figaro*" to improve the street illumination of Paris by manure fermentation from the numerous horses of the taxis and publicworks was not executed.

First digestion plant was built at a leper colony in Bombay, India in 1859. The first full scale application was in the 1890s when the city of Exeter, UK used the first unheated and unmixed tanks with significant operational problems due to solid settling and scum formation.

In the second half of 19th century, more systematic and scientific in-depth research was started in France to better understand the process of anaerobic fermentation. The objective was simply suppressing the bad odor released by wastewater pools. During their investigations, researchers detected some of the microorganisms which today are known to be essential for the fermentation process. It was Béchamp who identified in 1868 that a mixed population of microorganism is required to convert ethanol into methane, since several end products were formed during the fermentation process, depending on the characteristic of substrate.

One of the most significant scientific developments in agricultural biogas goes back when Buswell made his basic experiments on manure digestion in combination with most possible types of organic waste **(Buswell and Hatfield, 1936)**. Buswell became the father of co-digestion.

The energy crises in the 1970s prompted American research into alternative energy strategies, and AD was one such option. This push resulted in the first farm digester built in America in 1970 where the biogas could be used for heat and power.