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Developmental Study on Biogas Digester for Cooking and as an Alternative Fuel for Petrol Generators

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ABSTRACT

With the looming threats of climate change and global warming, the demand for sustainable fuels as healthier alternatives is growing sporadically. These renewable energy fuel sources cause little harm to our health and environment. This research work studied the processes involved the production of a bio-digester useful in producing Biogas fuel from organic waste materials. The focus is on a digester capable of producing clean biogas for urban and rural settings. The people that completely or partially depend on wood, kerosene or LPG gas for cooking. The available technologies, materials skills were fully investigated and discussed in this report. Technologies such as Simplex Optimization Technique, Pig-dung gas Technology, and co-digestion technique were investigated upon

Keywords: *Biogas Digester, Petrol Generators, Renewable Energy, Technologies*

1. Introduction

Biogas is a gaseous mixture generated during anaerobic digestion processes using waste water, solid waste (e.g. at landfills), organic waste, e.g. animal manure, and other sources of biomass (Welink et al., 2007). Anaerobic digestion is the biological degradation of biomass in oxygen-free conditions. In the absence of oxygen, anaerobic bacteria will ferment biodegradable matter into *methane (40-70%), carbon dioxide (30-60%), hydrogen (0-1%) and hydrogen sulfide (0-3%),* ***a*** mixture called biogas. Biogas is formed solely through the activity of bacteria.

Biogas can be produced on a very small scale for household use mainly for cooking and water heating. The feedstock example animal dung or sewage, is converted to slurry with up to 95% water, and – for small-scale applications – fed into a digester. Digesters come in many forms and sizes, which may range from 1 m3 for a small household unit to some 10 m3 for a typical farm plant and more than 1,000 m3 for a large installation (Larkin et al., 2004). Biogas production in such cases can be both continuous and in batches with digestion taking place for a period from ten days to a few weeks.

Biogas is a gaseous mixture generated during anaerobic digestion processes using waste water, solid waste (e.g. at landfills), organic waste, and other sources of biomass. Biogas can be upgraded to a level compatible with natural gas ('green gas') by cleaning (removal of H2S, ammonia and some hydrocarbons from the biogas) and by increasing its methane share (by removing the CO2). The resulting green gas can subsequently be delivered to the natural gas distribution grids. In developing countries, biogas could be an interesting energy option, in particular for those countries that rely heavily on traditional biomass for their energy needs.

Biogas technology is a manure management tool that promotes the recovery and use of biogas as energy by adapting manure management practices to collect biogas. The biogas can be used as a fuel source to generate electricity for on-farm use or for sale to the electrical grid, or for heating or cooling needs. The biologically stabilized by-products of anaerobic digestion can be used in a number of ways, depending on local needs and resources. Successful by-product applications include use as a crop fertilizer, bedding, and as aquaculture supplements.

Statement of Problem

The threats of the rising cost of cooking wood, kerosene, and obvious health hazards of these traditional fuels are increasingly alarming. There is an obvious need for more sustainable, cleaner, and cheaper options of fuel. Such options allow the processing of the waste resources like rotten food, kitchen waste, and human/animal waste to produce the valuable fuel they need to cook food, produce lighting and as well as run their petrol generators. There is therefore the need to make available bio-digesters capable of turning these wastes into useful gas fuels.

Aims and Objectives

The aim of this work is to develop Biogas Digester that will be used in producing gas for cooking and Electrical power generators. The objectives include: -

1. To characterize the form and quality of the energy available in biodegradable waste produce**d** in our domestic and industrial settings.

2. To review the available bio-digester technologies.

3. To design and develop a bio-digester capable of digesting these biodegradable materials into the fuel gas.

4. To test and evaluate the bio-digester using cooking gas burners and petrol generators.

2. Literature Review

Biomass is a renewable energy source not only because the biomass can re-grow over a relatively short period of time compared with the hundreds of millions of years that it took for fossil fuels to form. Through the process of photosynthesis, chlorophyll in plants captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates-complex compounds composed of carbon, hydrogen, and oxygen. Using biomass to produce electricity reduces our reliance on fossil fuels, the nation's primary energy source for electricity, and the largest contributor to air pollution and greenhouse gases. It is organic matter that is renewable over time and can be used as a source of energy (i.e., heat, power) or for its chemical components.

Common sources include:
I. Forestry crops & residue
II. Agricultural crops & residue
III. Animal residues
IV. Industrial residues
V. Municipal solid waste
VI. Sewage

When these carbohydrates are burned, they turn back into carbon dioxide and water and release the energy they captured from the sun.

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH4) and carbon dioxide (CO_2) otherwise known as biogas. These gases are produced from organic wastes such as livestock manure, food processing waste, etc. Anaerobic processes could either occur naturally or in a controlled environment such as a biogas plant.

Organic waste such as livestock manure and various types of bacteria are put in an airtight container called a digester so the process could occur. Landfilling is the main method for the disposal of municipal and household solid wastes or refuse. Although maintained in an oxygen-free environment and relatively dry conditions, landfill waste produces significant amounts of landfill gas (mostly methane) Municipal solid waste (MSW), anaerobic, and biomass are the major waste-to-energy technologies.

A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels, and various biogases. Similarly, bio-fossil fuels also have their origin in ancient carbon fixation. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price hikes, the need for increased energy security, and concern over greenhouse gas emissions from bio-fossil fuels.

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Cellulosic biomass, derived from non-food sources such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation.

Bio-diesel is made from vegetable oils and animal fats. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. In many ways, biomass is a new source of power. While wood has always served as a fuel source for fires and ovens and conventional heating methods, biomass energy advancements are a few steps beyond that. Now, these biomass fuel products are harvested and mass-produced, and used in everything from engines to power plants. Biogas is a source of renewable energy produced when biomass is subjected to biological gasification and methane gas is formed from the anaerobic digestion of organic materials. The wastes that are usually disposed of either into the sea, river, or on the land as solid amendment materials, which causes support for the breeding of flies, and constitute health hazards to people living around the area are converted into biogas by anaerobic fermentation (Ezeonu, 2002). Bio-digester technology simply degrades and converts the biodegradable wastes into usable water and gasses in an eco-friendly manner.

Anaerobic digestion is a process through which bacteria break down organic matter—such as animal manure, wastewater bio-solids, and food wastes—in the absence of oxygen. Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor, which is designed and constructed in various shapes and sizes specific to the site and feedstock. These reactors contain complex microbial communities that break down (or digest) the waste and produce resultant biogas and digestate (the solid and liquid material end-products of the AD process) which is discharged from the digester.

Multiple organic materials can be combined in one digester, a practice called co-digestion. Co-digested materials include manure; food waste (i.e., processing, distribution**,** and consumer-generated materials); energy crops; crop residues; fats, oils, and greases (FOG) from restaurant grease traps, and many other sources. Co-digestion can increase biogas production from low-yielding or difficult-to-digest organic waste.

Stand-Alone Digesters

Most stand-alone digesters accept and process feedstocks from one or more sources for a tipping fee. Stand-alone digesters can be operated as organics recycling businesses, community-based operations, or built by a municipality to manage residential food waste.

Other stand-alone digesters are built to process industry-specific wastes. This is common in the food and beverage industry. These digesters are co-located at processing plants and are designed to process a certain kind of material. These units typically do not accept other feedstocks from offsite sources.

The primary feedstock processed in stand-alone digesters is food waste. However, digesters built to process food waste can also co-digest other organic materials, such as yard waste, manure, and wastewater solids.

Demand for stand-alone digesters is increasing to address the increase of diversion of food waste from landfills.

On-Farm Digesters

On-farm digesters can bring great value to farmers. It can help farmers manage nutrients, reduce odors, and generate additional farm revenue. Dairy, swine, and poultry are the primary animal types for farms with digesters. On-farm digesters can also accept outside food waste as a feedstock. The most common digester system technologies on farms in the United States are plug flow, complete mix, and covered lagoons. The type of digester used on farms is typically determined by the manure management practices in place and the type of animal manure that is fed into the digester. Biogas collected from the anaerobic digester systems is often used to generate electricity, fuel boilers or furnaces, or provide combined heat and power.

Digesters at Water Resource Recovery Facilities

The term "Water Resources Recovery Facility" acknowledges their ability to produce clean water, recover nutrients (such as phosphorus and nitrogen), and reduce our dependence on fossil fuel through the production and use of renewable energy. The use of anaerobic digestion at WRRFs in the United States dates back to the early 1900s. Over the last century, there have been both advancements and setbacks in the development of technology. Anaerobic digestion is both a biological process and an engineered system that requires expertise in both disciplines for success.

The primary purpose of anaerobic digesters at WRRFs is to treat wastewater solids. WRRF digesters vary in a number of ways including size and shape; processing rate; the number of stages to the process; operating temperature; extent of pre-digestion processing; and types of mixing strategies.

3. Research Methodology

The process involves the bacteria which feed upon the fecal matter inside the tank, through an anaerobic process that finally degrades the matter and releases methane gas that can be used for cooking, along with the treated water.

The digester used for this research is 50,000litre capacity of Drum and 40,000litrecapacity of Drum for the gas holder (Fig 3.1). The study was carried out between August to November 2017 at Ibadan. The Pig dung was used to prepare the digester, which was collected from the slaughterhouse in Ade-Oyo, Ibadan, Oyo state. The total number of fattening Pig used was 1000 which have a weight of approximately 60kg, Total solid waste per kilogram is 0.3per kg, Density of dry matter in the fluids~ 50 km^{-3}**,** Retention time is 8-20days, Heat of combustion per unit volume biogas is (20MJm^{-3} at 10 cm water gauge pressure, 0.01 atmosphere), Burner efficiency is ~ 60%, Total wet manure per animal per day per kilogram is 3.3 per animal per day/kg. [johntwidell et al, 2006].

The biogas plant consists of a mixing tank, inlet pipe, Digester tank, outlet chamber, and gas holder, which is indicated in figure 3.1.

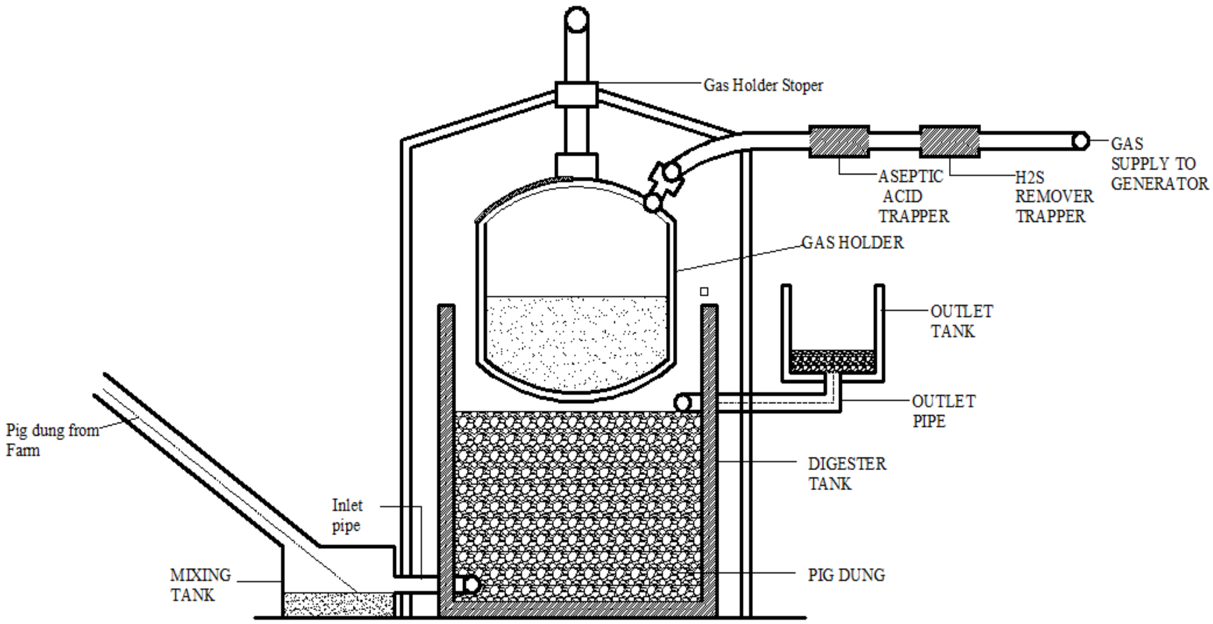


Figure 3.1: The Biogas plant (Floating Drum)

A typical biogas digester system consists of the following components:

1. Manure collection
2. Anaerobic digester
3. Effluent storage
4. Gas handling

Biogas from anaerobic digestion can be produced from a variety of biomass types. The primary source is manure from animal production, mainly from cattle and pig farms

The feedstock, e.g., animal dung or sewage, is converted to slurry with up to 95% water, and – for small-scale applications – fed into a purpose-built digester. Digesters come in many forms and sizes, which may range from 1 m3 for a small household unit to some 10 m3 for a typical farm plant and more than 1,000 m3 for a large installation (Larkin et al., 2004). Biogas production in such cases can be both continuous and in batches with digestion taking place for a period from ten days to a few weeks.

Summary of Biogas Plant Construction

1. The biogas plant consists of a digester Drum, where the pig dung is stored and microorganisms work on them and release gas.

2. The gas produced is collected in a drum known as a gas collector. In a floating type model, this tank is floating in the slurry and moves up and down based on the amount of gas stored in it.

3. A guide pipe is constructed which helps the gas collector drum to move up and down inside the digester drum.

4. Pig dung is fed through the inlet pipe inside the digester.

5. The fully digested slurry drains out through the outlet pipe. This can be collected, diluted, and used as fertilizer for plants.

6. A gas pipeline from the gas collector drum is now connected to the 120KVA Generator for lighting

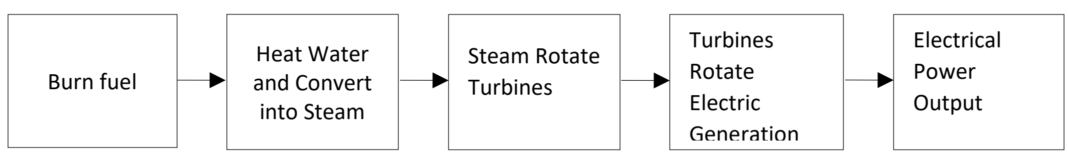


Figure 3.1 Biomass Electricity Generation Process

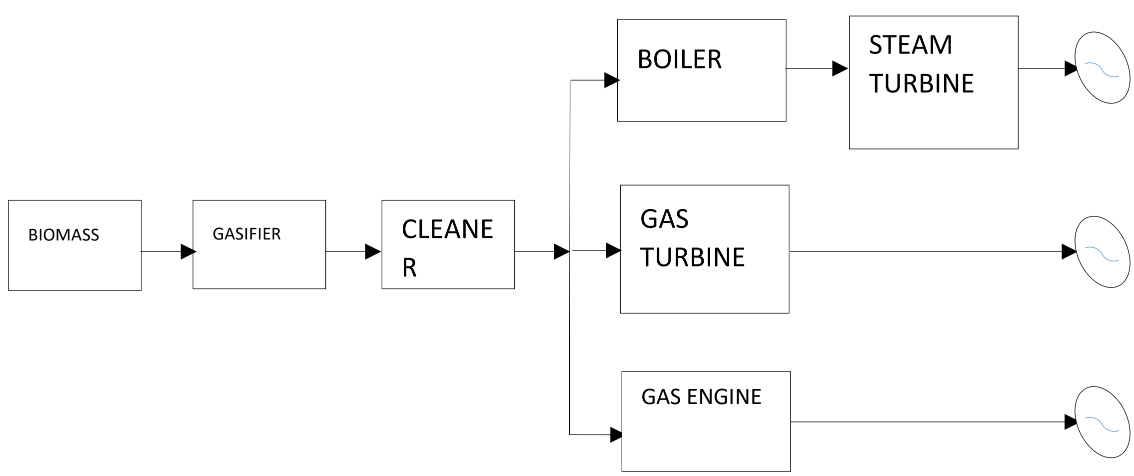
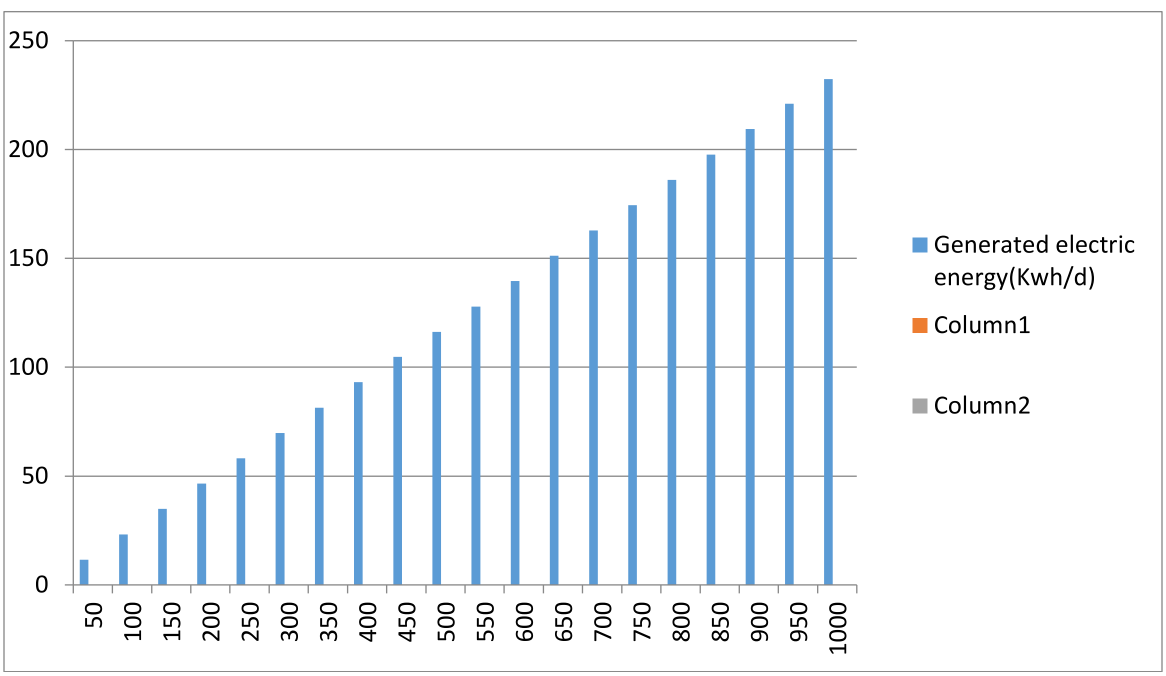


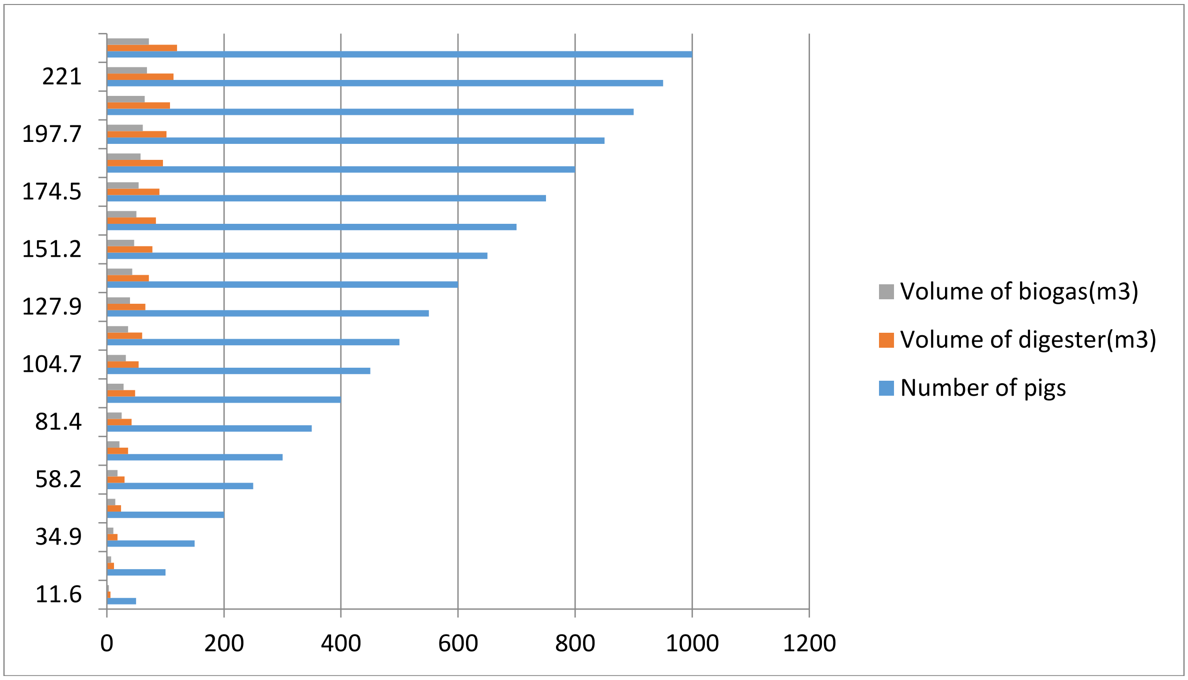
Figure 3.2: Block diagram of biomass electricity generation using gasifier

Table 3.1: Collected Empirical Data from Ade-Oyo at Ibadan in Oyo State

Number of Pigs	*The Volume of Digester (m^3)*	*The Volume of Biogas (m^3)*	*Generated Electric Energy (Kwh/d)*	*Generated Electric Power (Kw/d)*
50	6	3.6	11.6	0.5
100	12	7.2	23.2	1
150	18	10.8	34.9	1.5
200	24	14.4	46.5	2
250	30	18	58.2	2.5
300	36	21.6	69.8	3
350	42	25.2	81.4	3.5
400	48	28.8	93.1	4
450	54	32.4	104.7	4.5
500	60	36	116.3	5
550	66	39.6	127.9	5.5
600	72	43.2	139.6	6
650	78	46.8	151.2	6.5
700	84	50.4	162.8	7
750	90	54	174.5	7.5
800	96	57.6	186.1	8
850	102	61.2	197.7	8.5
900	108	64.8	209.4	9
950	114	68.4	221	9.5
1000	120	72	232.4	10

Graphical presentations of the empirical data collected





4. Result Analysis

Table 4.1: Comparing Optimized Electrical Biogas Power Output when the Volume of the Biogas is 0.133m³ and 3.6m³ Respectively

No of Pigs Dung	*Optimized Electrical Biogas Power when the Volume of Biogas is 0.133m³.*	*Optimized Electrical Biogas Power when the Volume of Biogas is Adjusted to 3.6m³*
50	0	0
100	0.3	6.2
150	0.1	5.1
200	0.2	5.4
250	0.2	5.4
300	0.2	5.4
350	0.2	5.4
400	0.2	5.4
450	0.2	5.4
500	0.2	5.4
550	0.2	5.4
600	0.2	5.4
650	0.2	5.4
700	0.2	5.4
750	0.2	5.4
800	0.2	5.4

5. Conclusion and Recommendation

Findings

i. To enhance biogas electrical power generation, optimize co-digestion has to be used.

ii. The mass of dung is directly proportional to biogas electrical power produced.

iii. The co-digestion system can tremendously increase electrical power generated with a mass of dung.

Conclusion

An optimized Co-digestion method for Biogas Electric power generation has been formulated. The Pig and poultry dung were used to prepare the digester, which was collected from the Department of Agricultural Science, ESUT, Enugu States. The Biogas was characterized in ESUT due to the availability of resources. The amount of methane gas in Biogas production will affect the Thermal rotating shaft of the Biogas Electrical Plant. Therefore, the more methane gas in the Biogas thermal engine the greater the power produced. MATLAB software was used to carry out simulations to develop an optimized model for Biogas power production with the aim to improve electricity accessibility and durability. The results of the research reveal the Empirical Biogas power production without and with an optimized co-digestion system. The result showed that biogas electrical power generated was 5KW/day and 6.145KW/d for pig and poultry dungs respectively while the co-digestion system is 11.14KW/day with a mass of 150kg. The results show the application of the co-digestion model which can be used to improve the power generation when the amount of methane gas varies with the speed of the thermal rotating shaft.

Finally, it shows that there is 44.84% of an increased biogas electrical power compared to Pig dung and a 38.115% increase compare to poultry dungs when optimized co-digestion method is applied at the same mass of dung.

Recommendation

Biogas electrical generation is renewable energy which is derived from animal dung and waste, hence for further research work to optimize Biogas electrical power generation there should be an incorporation of an intelligent agent to monitor and control electrical generation in other to enhance the efficiency of biogas electrical power generation.

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