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A Review on Biogas as an Alternative Fuel

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ABSTRACT

Anaerobic digestion, which produces flammable gas, mostly methane (CH4) and carbon dioxide, is the subject of the biogas technology (CO_2). Due to factors such as climate change, falling energy prices, increasing distributed generation, and environmental concerns, the conversion of biomass to energy has surged in recent years, rising from 65 GW in 2010 to 120 GW in 2019. High moisture wastes are more suitable for landfill, digestion, and anaerobic digestion procedures. The capacity of biogas plants was around 19.5 GW by the end of 2019. Organic wastes are the most widely used feed stocks for producing biogas from wastes, including household wastes (food, fruits, and vegetables) or public wet wastes (cafés and restaurants, daily markets, and enterprises' biological wastes), due to their high degradability and significant moisture content. These input items fall under the category of OFMSW (organic portion of municipal solid waste). With the addition of CH_4, biogas may be utilised to make transportation fuel or combined heat and power (CHP). When using biogas to create fuel for transportation, either energy is imported to run the plant or some of the biogas is utilised in a small CHP unit to generate the necessary power on-site. The potential profitability from CH_4 enriched biogas is greater when replacing Petrol than when replacing Diesel. When burning landfill gas is included in the "do nothing" scenario, importing brown energy for transportation results in higher greenhouse gas production than using gasoline or diesel. Transporting CHP fuel to meet on-site energy needs is the preferred strategy. Only 53% of the biogas produced by this system is exportable, which is a drawback.

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1. INTRODUCTION

Biogas, unlike fossil fuels, is fundamentally renewable since it is produced from biomass, and this source is effectively a reserve of solar energy via the photosynthesis process. Anaerobic digestion (AD) biogas will not only improve a country's energy basket position, but will also make a significant contribution to natural resource conservation and environmental protection.

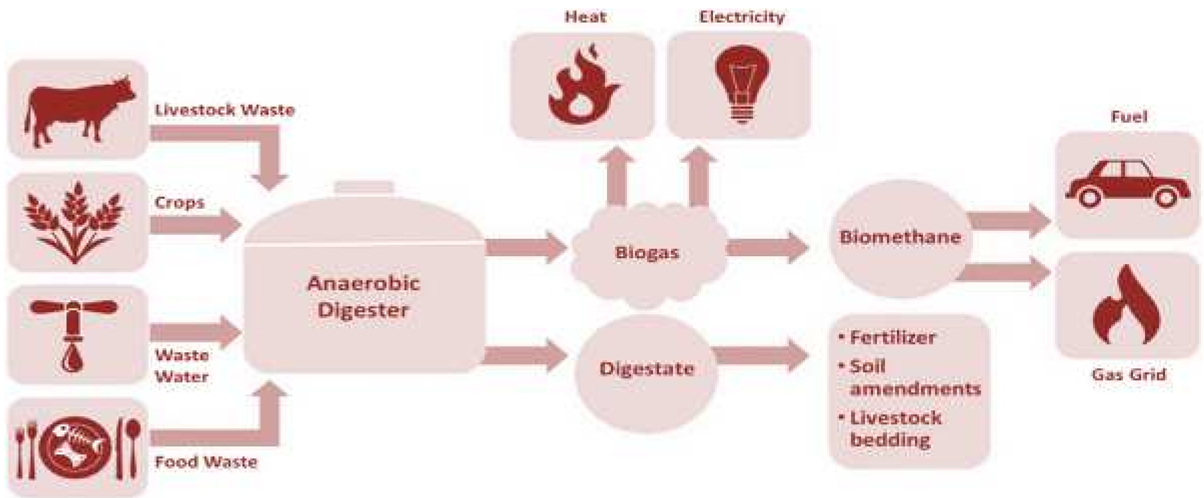

Figure 1 Biogas Production

Biogas is made up of naturally occurring biogenic material. This naturally occurring biogas spreads into the environment, and its main component, methane, has a significant negative impact on global warming (Bochmann and Montgomery 2013). Over the last several decades, methane has been used as an essential fossil fuel and converted to provide electricity, transportation, and heating. Nowadays, natural gas resources account for the majority of methane consumption and usage, although bio-methane generation from waste recovery methods has expanded significantly. Over the last nine years, its manufacturing capacity has increased by 4%. (From 2010 to 2018). Currently, around 3.5 Mtoe of biomethane is generated globally, and the potential for biomethane production today exceeds 700 Mtoe. Of course, this does not imply that methane conversion from all natural resources is practical. In other words, biogas infrastructures rely heavily on specific equipment and the availability of control and management systems.

As a result, a sustainable industry that generates bio-energy from renewable and green natural resources may be constructed and executed.

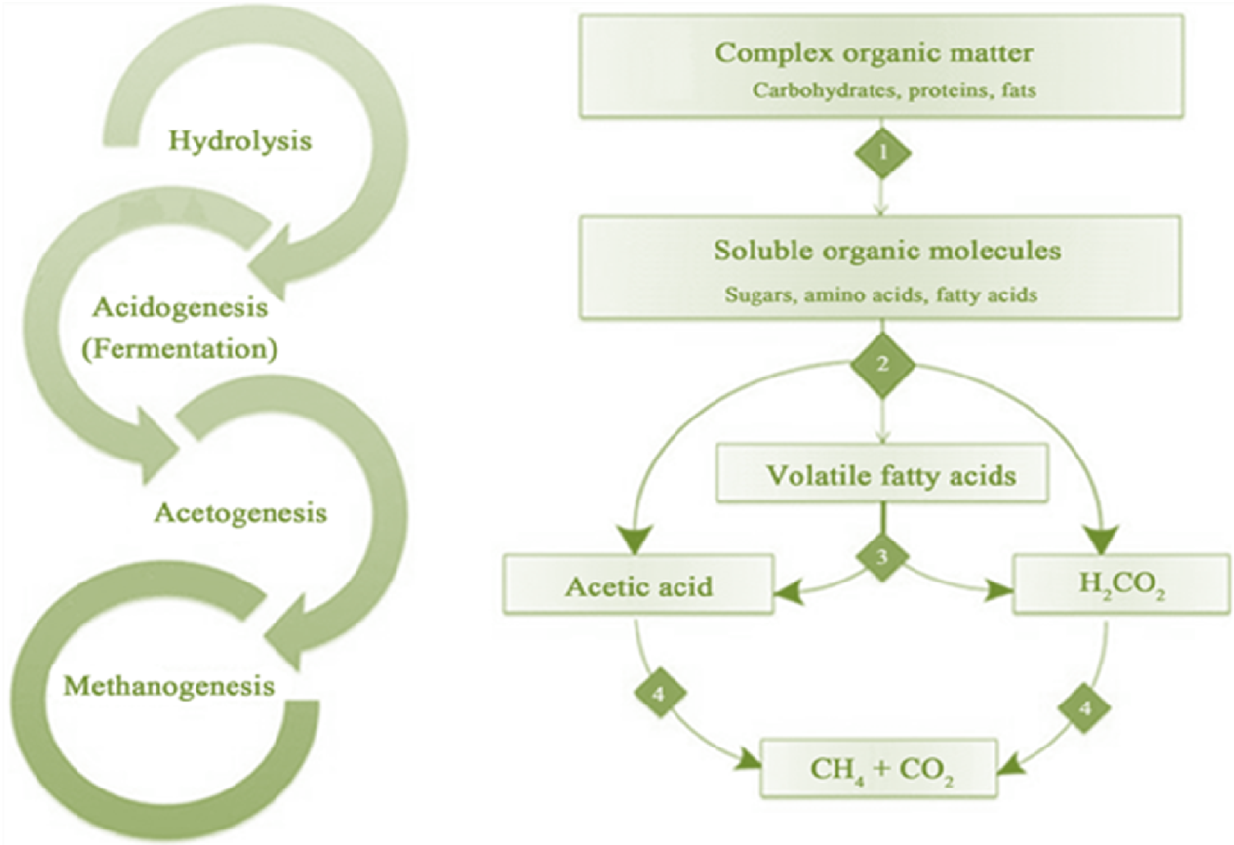

Figure 2 Microbiology of Biogas Production

1.1. Biogas Applications
Biogas is often regarded as conventional off-grid energy. Biogas may also be used to produce power. The following sections cover the numerous applications of biogas.

1.1.1. Electricity Generation
Because of technical advancements, less dependency on fossil-based energy, and reduced greenhouse gas (GHG) emissions, biomass power generation is presently the most popular and expanding market worldwide. Biogas has the ability to generate energy in power plants using internal combustion engines (ICEs) or gas turbines (GTs), which are the two most frequent power production techniques.

Micro gas turbines are especially appealing due to decreased NOx emissions and the ability to handle a variety of load needs. To address low/medium power load demands, several micro turbines ranging in size from 70 kW to over 250 kW can be used. The electricity can supply the necessary power to the nearby industry and businesses. With the advancement of electric vehicles, another cutting-edge use, particularly in developed nations such as Germany, is the usage of power for e-vehicles of a linked car-sharing association.

The main advantage of on-site energy generation is that it eliminates transportation losses and increases dependability owing to independence from a centralized grid that is largely powered by traditional fossil fuels. It also generates additional economic profit by meeting the needed in-house power consumption and selling the excess electricity.

1.1.2. Heat Generation

Biogas may be burned directly in boilers for heat generating solely. It is possible to slightly adapt natural gas boilers to run on biogas. Because farm biomass is a key biogas production source, the produced heat may be utilised to heat digesters, farm structures such as pig/sty housing units, greenhouses, aqua farming, cooling/refrigeration of farm goods, and drying reasons. The drying process in agricultural companies, such as the drying of dig estate, woodchip, grain, herbs, and spices, adds significant value to the farm economy.

Available heat for external usage, accounting for about 30-50% of generated heat, can be sold to a neighboring area for district heating/cooling, such as heating swimming pools. In addition to cooling power, an absorption chiller may be a contender for better utilization of heat via CHP (tri-generation). It can transform heat into cooling electricity at up to 70% efficiency.

1.1.3. Combined Heat and Power (CHP) Generation

Concurrent generation of heat and electricity using CHP systems is an operational strategy for improving biogas energy conversion efficiency. Only a small portion of the energy contained in biogas is consumed when converting it to power or heat. Typically, related power conversion productivity in these sorts of systems is between 30 and 40%, but it is reduced when biogas is used as a replacement to refined and simply natural gas.

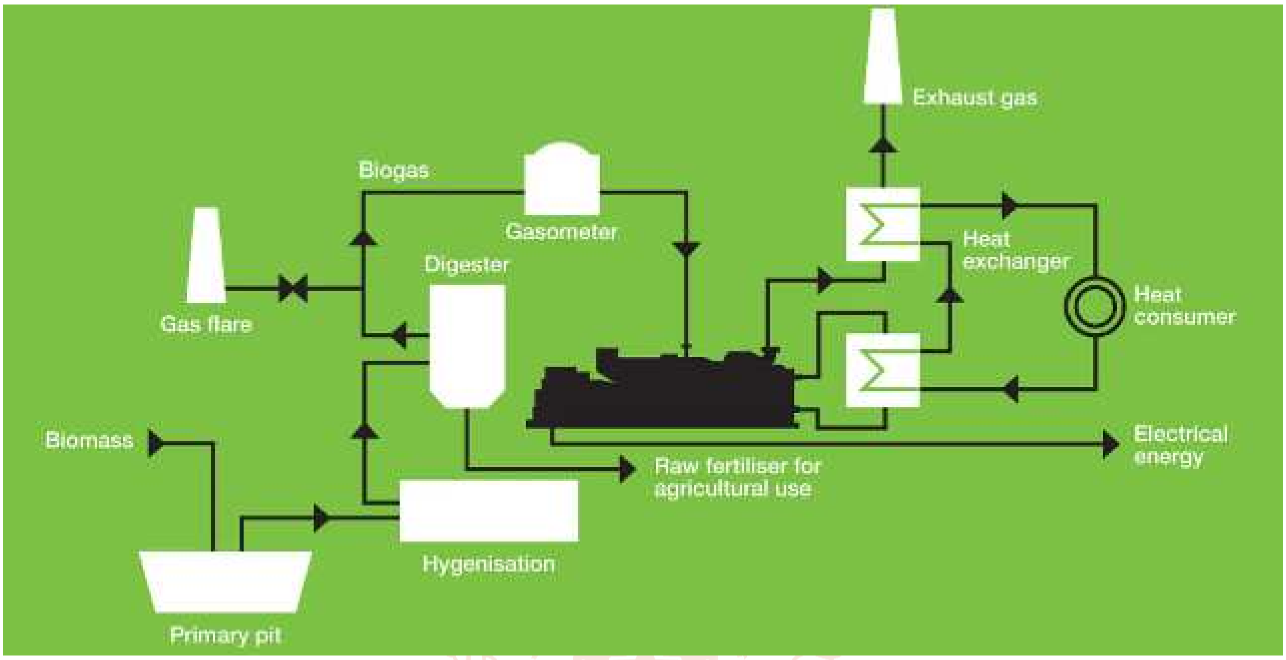

Figure 3 Biogas CHP Generation

CHP facilities have the benefit of using high-temperature exhaust gas from the electricity production subsystem (ICEs or GTs) as a source of useful heat for many of the previously listed heating needs. Although simple plants' electricity generation efficiency is only 20-45%, a larger portion of energy (around 60% of the utilised energy is converted to heat that is reused by heat recovery systems, making it more appealing when there is a high heat demand. This significantly improves system efficiency and plant payback period, making dispersed generation the most popular biogas use. Extra power might be given to the national grid, while excess heat could be sold for local district use.

A CHP cycle has a high efficiency of up to 90% and may produce 35% and 65% of the produced electricity and heat, respectively. In this situation, some thermal energy is used to heat the process, while approximately two-thirds is used for external purposes. Some proposed models for biogas-based power plants neglect the utilizations of produced heat and focus solely on generating electricity. This strategy has no economic justification and must utilise all of its thermal potential.

1.1.4. Transportation Fuel

As an alternative to fossil natural gas, biogas converted to biomethane (through upgrading and cleaning) may be easily used in natural gas-powered cars. Using biomethane as transportation fuel results in impressively low GHG emissions, making it a viable renewable fuel source.

In terms of environmental and economic factors, biomethane appears to be an excellent choice to replace fossil-based fuels. However, when biomethane is used in sophisticated hybrid or fuel cell vehicles (FCVs) instead of existing biodiesel or ethanol-powered ICE vehicles, overall efficiency is much enhanced.

In general, biogas may be converted into transportation fuels (bio-CNG) that can be stored for later use, such as liquefied biogas (LBG), syngas/hydrogen, methanol for gasoline synthesis, ethanol, and higher. Compression and liquefaction are prominent physical ways for converting biogas into bio-CNG and LBG, but catalytic reforming is the major chemical method for obtaining syngas. Syngas may be transformed into a range of alcohols such as methanol, ethanol, and butanol via Fischer-Tropsch synthesis (FTS) or fermentation. This alternative fuel has previously been used in the European Union and the United States. In Sweden and Germany, for example, many cars in urban public transportation run on biogas, either as 100% methane (CBG100) or blended with natural gas (e.g., CBG10 and CBG50).

1.1.5. Hydrogen Production

Because of its great energy production potential, hydrogen has numerous intriguing applications in renewable energy and the chemical sector. Hydrogen has the most energy per unit mass (121.000 kJ/kg). The hydrogen council estimates that it will contribute roughly 18% of global final energy use by 2050. As an emerging energy use, hydrogen is best used in fuel cells to generate electricity, heat, and perhaps water. Furthermore, hydrogen has several uses in the chemical industry, including food processing, hydrogenation processes, ammonia and methanol production, Fischer-Tropsch synthesis, and pharmaceutical manufacture, among others.

Hydrogen is a clean transportation fuel, but syngas, as previously noted, may be utilised as a feedstock for alcohol manufacture. With recent developments in reforming processes, biogas may now be directly upgraded to syngas using dry or steam reforming without the need for carbon dioxide removal.

1.2. Biogas Production

Biogas generation may be divided into two types of fermentation processes: dry and wet. The total solids content in the fermenter is less than 10% for wet digestion. To treat solid substrates, liquid manure must be used to create a pumpable slurry. As shown in Fig. 4, the biogas generation technique contains four critical phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

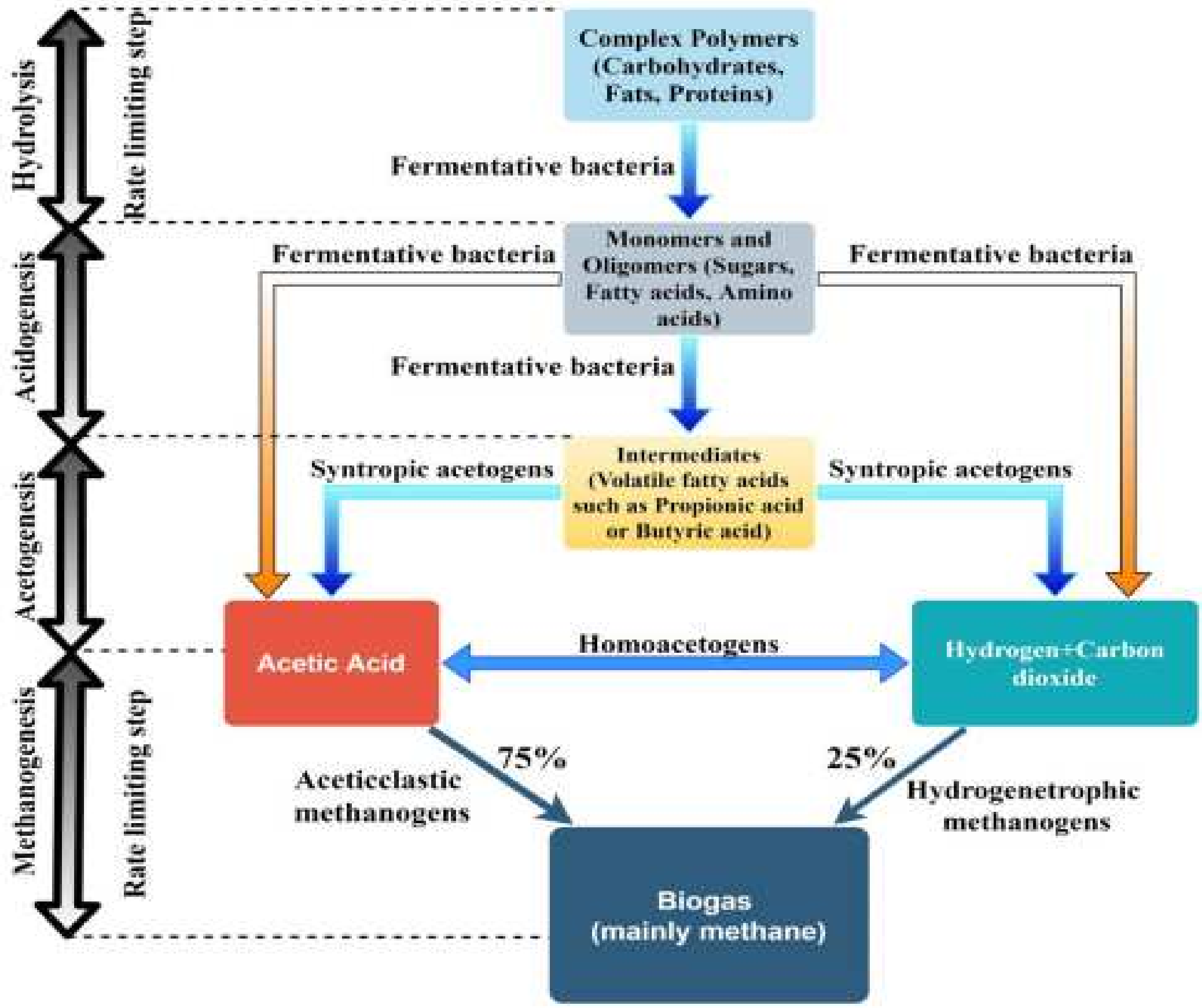

Figure 4 Biogas Production Procedures

In dry digestion, on the other hand, the total concentration of solids in the fermenter ranges from 15 to 35%. The stability of wet digestive procedures is greater than that of dry techniques. Wet digesting procedures are increasingly common in the agriculture sector.

The chemical process for producing biogas is divided into three step:
Stage 1 - The biomass feed in a digester where organic matter containing a complex component (carbohydrates, proteins, and lipids) is hydrolyzed (broken down in the presence of water). Polymer molecules are broken down into little monomer units. These activities are completed in a digester in one or two days at 25 degrees Celsius [4].

Stage 2 - Acid formers are anaerobic bacteria that can thrive without oxygen and create acetic and propionic acids. Carbon dioxide is also emitted at this stage, which takes roughly one day at 25 degrees Celsius.

Stage 3 - During this stage, anaerobic bacteria produce methane, carbon dioxide, and a little amount of hydrogen gas. At 25 degrees Celsius, these processes take roughly two weeks to complete.

2. LITERATURE REVIEW

This study provides a thorough examination of papers that illustrate the many conversion processes undertaken across the world. The resources for producing biogas, as well as treatment procedures, are described. The impact of many regulating criteria, such as feedstock types, pretreatment techniques, process development, and yield, on biogas productivity is highlighted.

Laboya et al. (2010) explore the significance of biogas as a source of alternative energy. A survey was conducted to determine the quantity of biogas that can be produced from various feedstock. A realistic laboratory size experimental design was also carried out utilising agricultural waste to investigate the effects of Alkaline (NaoH) on the amount of biogas created using a mixture of pineapple, plantain, and cassava peelings as the feed stock. The results show that a large amount of gas is produced when the working conditions within the digester are kept at a moderately alkaline level. Further research reveals that the digester temperature maintained within the range of 27 to 35.5°C throughout the trial.

Md. Forhad et al. (2013) examined the generation of biogas from various fermentable materials using a small-scale model biogas plant. A batch type fixed dome biogas plant model is developed and built to produce around 0.5-1.0 m^3 of biogas. Cow dung, chicken manure, and water hyacinth were chosen as fermentable ingredients. Biogas was studied and compared from cow dung, chicken waste, and water hyacinth. Biogas production from cow dung, chicken manure, and water hyacinth was found to be 0.034 m^3/kg, 0.058 m^3/kg, and 0.014 m^3/kg, respectively. Poultry waste generated the most gas 0.026m^3 on the eighth day, whereas cow dung and water hyacinth produced the most gas 0.0263 m^3 and 0.012m^3 on the 26th day, respectively. The percentage of methane content (the primary element) in biogas produced from various fermentable materials is nearly same.

Tsunatu et al. (2014) investigated the kinetics of agricultural waste biogas generation when infected with cow manure. Dung/poultry droppings under mesophilic settings with 8% Total Solids and a retention duration of 55 days. The modified first order kinetic model was created to investigate the kinetics of the digesting process's biodegradation. The rates of substrate biodegradability and removal of the biodegradable fractions of the substrate are given by a plot of 1/t(ln(dyt/dt)) against 1/t from the model. Among all substrates, maize cobs (MC) have the greatest short term biodegradability index of 1.5827, while bio-digester D (SB) has the lowest rate of biodegradable fractions (k) of - 0.302. Bio digester C (Rice Straw) produces the most biogas, with a cumulative volume of 692.9ml and an R2 value of 0.8424, while bio digester D (Sugarcane Bagasse) produces the least, with a volume of 185.9ml and an R2 value of 0.6479.

Sangeetha et al. (2014) investigated the viability of biogas from chicken waste and a combination of poultry and fish waste. Fish wastes contain a high ammonia nitrogen concentration and have a high value as a source of high valued organic carbon for methane synthesis. In research, they discovered that poultry waste created more biogas than chicken droppings. They have co-digested chicken waste and cow dung in a 3:2 ratio, as well as codigested poultry waste with a mixture of fish waste and cow dung in a 2:2:1 ratio. The water displacement method was used to compare biogas output in this case. The digesters had a capacity of about 20 liters, and wastes were fed into them in various ratios. Biogas was collected in water bottles containing a Braine solution of sodium hydroxide, and the rise in solution level indicated the quantity of anaerobic digestion biogas generated. After two weeks of digestion, the Braine solution level increased significantly, showing that biogas generation was high in the mixture of chicken waste, fish waste, and cow dung 185.9ml with an R2 of 0.6479.

According to **Ravi Agrahari and Tiwari (2015),** kitchen trash is the greatest solution for biogas generation in a community level biogas plant. When bacteria breakdown organic materials in the absence of air, it produces it. Biogas includes around 55% methane and 30% carbon dioxide. Biogas has a significant calorific value (about 4700 kcal or 20 MJ at roughly 55% methane concentration). After dewatering and cleaning, the gas may be successfully used for power generation using a biogas-based power generation system. Furthermore, the slurry created in the process provides essential organic manure for agricultural and soil fertility maintenance. In this work, an attempt was made to evaluate the performance of various kitchen waste ratios in a metal constructed portable floating type biogas plant with a volume capacity of 0.018 m3 for outdoor climatic conditions in New Delhi, India. For all measurements, each biogas plant has a 30 kg slurry capacity in a batch system.

According to **Rama Dhanariya et al. (2016),** biodegradable wastes such as kitchen garbage and animal manure are utilised to make Biogas, a potent greenhouse gas. Anaerobic digestion (AD) is a treatment that composts these wastes in the absence of oxygen, resulting in biogas that may be utilised to create heat and electricity. Producing renewable energy from biodegradable garbage contributes to addressing the energy dilemma. It is essentially a regulated and contained version of the methane-releasing anaerobic decomposition of organic wastes. AD generates biogas that contains around 60% methane and 40% carbon dioxide (CO2). In addition to biogas, AD generates a solid and liquid residue known as digestate, which can be used as a soil conditioner to fertilise land. The amount of biogas produced and the quality of the digestates produced will differ depending on the feedstock utilised. More gas will be generated if the fuel decomposes more quickly.

According to **Vipul Vaid and Shivangi Garg (2017),** biogas is a valuable renewable energy source comprising 55% methane and a sustainable form of waste disposal. It has no geographical boundaries and does not require complex technology to produce energy; it is also very simple to use and deploy but has yet to realise its full potential. These resources, when combined with new and developing conversion technologies and suitable energy policy, have the potential to make biogas a significant contribution to the renewable energy landscape. Biogas may help decentralise energy generation, and the immediate benefit of having a small biogas system is the cost savings over using kerosene or LPG for cooking. Kitchen waste biogas systems are 800 times more efficient than traditional biogas systems. Kitchen trash has a high calorific content and nutritional value to bacteria, which increases the efficiency of methane generation by many orders of magnitude.

Nabila Laskri and Nawel Nedjah (2018) conducted research on two distinct substrates: biodegradable garbage from a landfill and sludge from a wastewater treatment facility using a natural lagoon. They observed the progress of organic matter breakdown in both tests, which were conducted in a one-liter sealed digester. The biogas generated by the anaerobic digestion of the two substrates highly combustible, containing more than 64% CH4. When the volume of biogas created during the digestion of the two substrates of digestion was compared, we discovered that the volume collected from sludge waste is more than ten times more than the volume of biogas produced with organic matter in the landfill. The volume of biogas generated is always a function of digestion residence time and organic matter content in the experiment. The sludge's COD reduction percentage was calculated to be 87.3%.

The anaerobic treatability and methane production potential of three distinct cotton wastes, namely cotton stalks, cotton seed hull, and cotton oil cake, were evaluated in batch reactors by **Iscia and Demirerb (2019).** Furthermore, the effects of nutritional and trace metal supplementation were studied. Biochemical methane potential (BMP) studies were carried out for two distinct waste concentrations, namely 30 and 60 g/l. Cotton waste may be handled aerobically and is an excellent source of biogas, according to the findings. In the presence of basal medium (BM), 1 g of cotton stalks, cotton seed hull, and cotton oil cake generated approximately 65, 86, and 78 ml CH4 in 23 days, respectively. The addition of BM has a very favourable impact on biogas output.

Ezeand Elijah (2020) worked on blending various fuels to run an internal combustion engines. For example, a study of performance and exhaust analysis of petrol engine using methanol-gasoline blends at 2000rpm and variable load condition at various blend condition produces promising brake power, brake specific fuel consumption, brake thermal efficiency and lower fuel consumption when compared with that runs on pure petrol. Carbon monoxide CO, Carbon dioxide CO_2 and Hydro carbon HC emissions also decrease when using a methanol-gasoline blend.

3. CONCLUSIONS

Global population growth has raised food and energy demand, especially in developing countries. This has put pressure on energy production and consumption, which is now linked to greenhouse gas emissions and climate change.

Although there is great potential for biogas to provide clean energy to both rural and urban populations, there has been growing concern over the large number of non-operational and abandoned biogas facilities, raising the issue of the sustainability of biogas technology for dependable biogas fuel production, delivery, and use. In India's Village Energy Security Program (VESP), for instance, 65 of 75 combined biogas and biomass gasification projects were commissioned, but only 42% of them were operational by the project's end, which was at odds with expectations by policymakers to meet the entire energy needs of rural communities.

With a present potential of well over 13,500, the United States now has a little more than 2200 operational biogas plants. A reliable, cost-effective, efficient, and abundant energy source with the least carbon footprint is needed more and more. Despite the fact that this waste may be converted into valuable energy and money, New York City alone spends around $400 million to transport almost 14 million tonnes of trash for incineration.

Biogas technology may be used to produce sustainable energy from crop and animal waste for heating and power purposes. The finished product is successfully utilised as fertiliser in rural farms and households, lowering handling and disposal costs. The usage of biogas energy has the potential to raise the socioeconomic status and quality of life of rural households all over the world. The development and testing of a biogas-petrol mixture for use in spark-ignition engines is the main subject of future work.

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