Technium Vol. 25, pp.83-93 (2024)
ISSN: 2668-778X
www.techniumscience.com

Study the process of producing methane gas (CH_4) used for industrial purposes using the method (Biogas)

Araa Ali Hadi*, Noor Mahmood Mahdi

Department of Basic Sciences, College of Dentistry, University of Kerbala, Karbala, 56001, Iraq

Abstract:

The methane gas (CH_4) production includes many conditions and capabilities, it is useful for industrial purposes, and can be produced in a biological methods called (biogas). This technique depends on the anaerobic fermentation process of organic waste and is carried out by bacteria to give an organic fertilizer that is rich in protein and nitrogen, therefore it is a suitable, promising technology for a triangle (energy, development, and environment). This mixture is a flammable gas resulting from the fermentation of organic matter away from air by anaerobic bacterial microbes resulting in the formation of methane (NH_4) at a rate of (75%), and carbon dioxide CO2 by (20%), and the rest the ratios are few hydrogen (H_2), nitrogen (N_2), and hydrogen sulfide H_2S. And that the methane gas (CH4), which will be a colorless gas, ignites without smoke from it, creating a highly heated blue flame, and is lighter than the air, with a burning temperature of about (700 C).

Keywords: Methane gas (CH_4), Biogas method, Anaerobic fermentation.

Introduction

Methane is referred to as one of the types of colorless and odor gases, and the gas is characterized by it occurring naturally in the nature as a result of many human activities, and methane is the simplest member in the paraffin chain of hydrocarbons. Chemically, the symbol CH4, and despite its use in several practical fields, there is a multiplicity of methane damage to humans and must be used with great care to avoid exposure to its risks. Methane is classified as a green-house gas and has been identified as a significant contributor to the phenomenon of global warming. When considering emissions on a per-ton basis, methane has been found to have a far higher impact than carbon dioxide, with estimates ranging from 28 to 34 times greater. Therefore, it can be observed that a methane emission of one tonne is equivalent to around 28 to 34 tonnes of carbon dioxide CO_2 equivalents (1). When considering the methane emissions resulting from the production of biogas, it is crucial to acknowledge that methane (CH_4) emissions are also present in natural gas facilities, alternative manure treatment methods, and landfills. As time progresses, there is a growing need to limit glasshouse gas emissions. By the year 2017, there is a requirement to achieve a savings of 50%. Starting from 2018, for biofuel production facilities that commenced operations after January 1st, 2017, the minimum savings target is set at 60% (2). The sustainability criteria encompass the examination of methane (CH_4) emissions and the measurement thereof in biogas facilities. Discussions pertaining to this topic have been persistently taking place throughout various regions in Europe and beyond. Numerous initiatives have been undertaken with the aim of mitigating the extent of losses incurred. Various approaches and methods have been employed to conduct the measurements, and the literature also contains methane emission statistics that are based on certain assumptions. Methane emissions to the atmosphere can occur at many stages within biogas production and upgrading facilities. The primary sources of emissions in biogas production facilities are ventilation systems, buffer or storage tanks, digesters, digestive storages, and dewatering equipment. The primary sources of emissions at biogas upgrading facilities include the off-gas, ventilation systems, and analytical instruments. In addition to methane being classified as a glasshouse gas, there are various other justifications for the imperative to reduce these emissions. These include considerations of safety, economic factors (3). In spite of the multiple damages of methane gas on humans, it is used in many practical fields, as it is an important source of hydrogen gas and some organic chemicals, in addition to its more common use as fuel, as many places in the world use natural gas made from methane in a way It is essential in addition to ethane and propane as a cooking fuel, and is used in some countries such as Brazil to run cars, as it produces many other materials; and some of them are mentioned. And methane is one of the simplest hydrocarbons present on the surface of the earth completely; it is also distinguished that it is found everywhere in the solar system and is also very large, it is found on the surface of Mars, Jupiter, comets and other planets astronomical bodies, and this gas is produced in several ways. In addition to the generation of biogas from agricultural and livestock wastes, the co-digestion of wastewater from wastewater treatment facilities and municipal organic waste has been identified as another viable source of methane-rich biogas (4). Methane is sourced from geological deposits and can also be derived from various aquatic environments such as swamps, seas, and oceans. Additionally, it is obtained through the decomposition of organic matter, as our ongoing research indicates. Furthermore, methane extraction from coal is another viable method. In its natural form, methane lacks odour; however, during manufacturing, sulphur is introduced to aid in the detection of gas leaks. This gas has been utilised since antiquity. During the thirteenth century, the Chinese implemented tank systems to enclose sewage, resulting in the creation of a substance with potential for energy generation. Certain authors have directed their attention towards the potential integration of the Rankin Organic Cycle (ORC) as a bottoming cycle within the Cogeneration Unit, with the aim of enhancing the overall electrical output of the system (5). On the other hand, cellulose based organic material such as tree leaves and celery produced the least amount of methane because of their low percentage of volatile solids.

2.Experimental aspect:

2.1. Type and composition of waste:

Since the process of producing biogas is a microbial decomposition process, we find that gas production depends mainly on the quality and contents of organic materials in the waste that go into the anaerobic fermentation process and the waste used comes from many and varied sources, including what is easy to digest such as human, animal and poultry waste the remnants of some crops and residues resulting from the food industry, and there are some wastes that have less degradation, such as firewood and tree residues (6).

2.2. Temperature:

It is known that the rate of chemical reactions and the rate of feeding and growth of microorganisms depends on the temperature, this rate increases with the increase in temperature in the possible range necessary for the life of these microbes (7, 8).

2.2.1. <u>Psychrophilic Bacteria.</u>

It works at low temperatures ranging between (10-25) ° C , and that the production of gas in such conditions of temperatures is not common and fermenters often face the problem of starting the process as it can be solved by using bacteria from the second group working in temperatures exceeding (30 ° C).

2.2.2. *Mesophilic Bacteria.*

The most suitable working temperature ranges between (25-37) degrees , and fluctuates between + _ 2 degrees.

2.2.3. Thermophilic Bacteria.

It works at temperatures ranging between (55-60) degrees , and is very sensitive to fluctuation in high temperatures.

2.3. pH:

The organic wastes at each stage of digestion, PH are subject to change, they are between (2-6) so they are few in the first stage and in the first three weeks of the process of decomposition and fermentation, gradually escalating, the pH increases over time from volatile acids and nitrogen compounds producing methane This is because microbes are at the top of their activity.

2.4. Solids Concentration:

Biogas production depends on the concentration of the primary solids in the residue and the rate of gas production increases by increasing the concentration in the fermentation solution to a certain extent. Livestock droppings are mixed by 1-10%, but the efficiency of converting the organic material into gas decreases with increasing the concentration of solids in the fermentation solution. .

2.5.Nutrients and carbon nitrogen ratio:

This ratio is related to the nutritional elements in the organic wastes , and it is an important percentage and a factor (P, Fe, Ni, S, C, N) is essential for the success or failure of the decomposition process for the organic materials. The nutrients are very important to maintain the activity of the bacteria participating in the anaerobic digestion process.

2.6. Add the initiator:

At the beginning of the operation of the biogas units, we find that the bacteria multiply at the beginning very slowly, therefore the necessity of adding a starter from another active source or from a successful fermenter has arisen, therefore a starter with a volume (5%) of fermentation solution is used from an active working unit or is prepared in a separate unit for this Purpose Or the carcass residues or wastewater residues are used to start fermentation activity (9).

2.7.Stirring the contents of the digester:

The process of stirring the contents of fermented biogas daily is very important and this process has many benefits, including:

1- Stirring makes organic waste in permanent contact with bacteria, which leads to the highest biological reaction rate.
2- For stirring helps to smooth the distribution of temperature.
3- It prevents the formation of solid and separate layers in the fermentation solution.
4- The produced gas is easy to escalate.

The anaerobic fermentation process is affected negatively to varying degrees by the presence of some heavy metals such as (S, Fe, K, Na, Ca).

2.8. The stages of biogas production are:

1- The stage of producing organic materials.

2- Acid production stage.

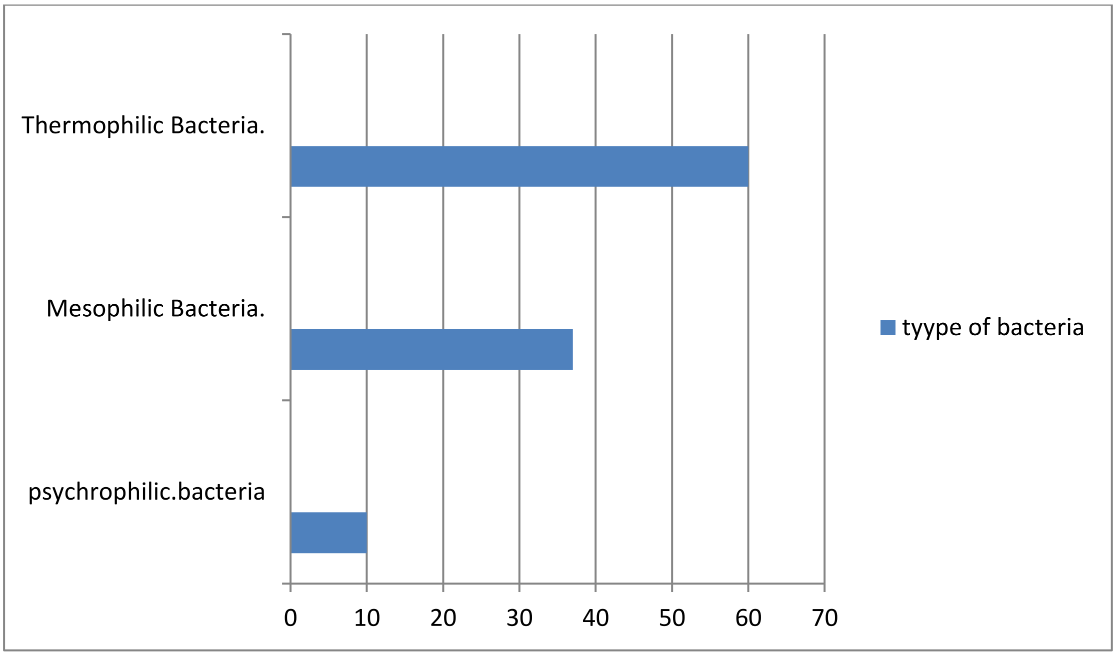
3- The stage of methane production.

3.discussion

In general, the wastes used must be highly susceptible to degradation to produce a large amount of gas and have a high carbon content in the form of cellulose and protein sugar. The waste must contain a small percentage of lignin that is difficult to disassemble through biological activity. When using residues rich in non-dissolved carbohydrates or rich residues reduced to liquid carbohydrates, it was found that the acidity rate started at the beginning of the fermentation process, and this PH level is less than 6.5 in decline caused by the rapid rate of production of fats and acids and the slow rate of bacterial use of these acids which low acidity rate. The natural properties and composition of organic waste determine the PH that kills it because of its suitability for anaerobic digestion and its ability to produce bio gas. The higher temperature adversely affects the enzymes during the anaerobic fermentation process and reduces the feeding rate and the process occurs (97 ° C), and the methane producing bacteria are - the production of methane gas in a wide range of temperatures ranging from the types of bacteria most affected by fluctuating temperatures and other types of Bacteria, especially those producing acetate, can grow and function efficiently even at low temperatures. Methane bacteria have been classified into three groups according to their temperature adaptation. In order to produce a fixed amount of gas, there must be a pH of approximately (7.5). The anaerobic digestion process is carried out with high efficiency , microorganisms grow better in neutral media (10). We can show you the rate of chemical reactions, the rate of nutrition, as well as the growth of microorganisms depending on the different temperatures as shown in the above **table (1)**:

Type of bacteria	**Level of temperature**
Psychrophilic Bacteria.	**(10-25 ° C)**
Mesophilic Bacteria.	**(25-37 ° C)**
Thermophilic Bacteria.	**(55-60 ° C)**

So that this rate increases as the temperature rises in the possible range that is necessary for the life of these microbes and their effectiveness for the desired purpose , as is Illustrated in **shape (1)**: to a way that clearly shows this relationship.



Shape (1): The illustration shows the relationship between the bacteria type and temperature and the effectiveness of each type of bacteria at the appropriate temperatures, to obtain the required result in the production of methane gas according to the sequence of steps.

It can be treated by two ways:

1\ Pause the feeding process of the fermenter until the methane bacteria find enough time to reduce the percentage of fatty acids.

2\ Add alkaline chemicals to neutralize acidity, such as calcium hydroxide , lime water and sodium carbonate.

We can show you the rate of chemical reactions, the rate of nutrition, as well as the growth of microorganisms depending on the different temperatures as shown in the above table, so that this rate increases as the temperature rises in the possible range that is necessary for the life of these microbes and their effectiveness for the desired purpose, as is Illustrated in a way that clearly shows this relationship. The amino acids produced from the hydrolysis: are a structurally diverse group , and their degradation is therefore performed by a number of different routes - enzymes. In order to obtain a high production of biogas, it is necessary to provide the materials and nutrients necessary for the activity of the bacteria (11). The bacteria consume carbon at a rate 30 times higher than nitrogen. The carbon provides the bacteria with the optimum energy. The wastewater deposits and the bio-fermentation sediments are considered the best types of starter, because they do not contain inhibitors or mineral elements. The addition of the starter leads to a significant increase in the production of biogas and a rise in the proportion of methane. It was found that stirring increases the volume of gas produced from fermentation that works with human waste to (8%). In sewage treatment brewers, stirring is carried out by pumps or air circulation or a vacuum tube provided with a flip-flop at the bottom. But these means are expensive, especially stations or small brewers, and there are some adjustments in the designs of these brewers that can achieve the purpose of flipping if the entry and exit openings are modified in a way that does this or by using vertical entry pipes to create a difference in pressure that makes the suspended waste flow under this pressure and when it exits in the bottom agitates the suspended substances dissolved in water.

An increase the concentration of nutrients necessary for the growth of bacteria, such as often occurs if the precipitate is left for a period longer than it should be. Symptoms of poisoning at minimum levels slow or decrease in the rate of gas production and in severe cases the entire chemical process stops due to poisoning and death of bacteria, and methane bacteria are more sensitive and affected food poisoning (12). Therefore, some substances are not allowed to reach fermentation, such as pesticides, disinfectants, etc., because they kill methane bacteria. The amino acids have the highest physiological importance arising from the decomposition of proton materials, and they are considered to be alkaline and acidic at the same time, and the oxidation process requires the participation of many types of bacteria that can be classified into the following groups:

3.1. Decomposition and fermentation bacteria:

These bacteria convert organic compounds such as carbohydrates, proteins and fats into sugars, starches and amino acids, as well as higher fatty acids, neutral compounds higher than methanol, and simple compounds of acetic acid.

3.2. bacteria producing hydrogen and acetate:

These bacteria act at the end of the first stage converting the previous converted products into hydrogen and acetate.

3.3. Acetate-producing bacteria:

These work in a wide range of mono- and complex organic compounds and carbon atoms and convert them into acetic acid.

3.4. Methane bacteria:

These bacteria use hydrogen, carbon dioxide, the produced acetate and methanol and convert them into methane, and the main source of gas production is acetic acid.

Fermentation products possess residual chemical energy due to incomplete oxidation, although they are regarded as waste byproducts due to their inability to undergo further transformation without the presence of oxygen or other strongly oxidising electron acceptors. Consequently, the efficiency of adenosine triphosphate (ATP) generation by fermentation is comparatively lower than that of oxidative phosphorylation, as the pyruvate molecule undergoes complete oxidation, resulting in the formation of carbon dioxide (CO2). While the recognition that the fermentation process primarily arose from the interaction of microorganisms constituted a significant breakthrough in understanding during that period, the fundamental essence of the fermentation process itself remained unelucidated. Furthermore, it was not definitively established that microorganisms, which were consistently observed, were indeed responsible for the occurrence of fermentation. Numerous scientists, including the renowned figure Pasteur, have effectively endeavoured to isolate the fermentation enzyme from yeast (13). They all accused the successful opportunity when, in 1897, the German chemist Eduard Bouchner managed to confine the yeast and extract juice from it, then he found what surprised him that this "dead" liquid has the ability to ferment a glycemic solution, forming carbon dioxide and alcohol just as much as living yeast. 15th] The unknown "brewers" behaved and interacted just like organized brewers (14). Since then the term enzyme has been used and applied to all ferments. It was then understood that the fermentation process is caused by enzymes produced by microorganisms. In 1908, Bouchner received the Nobel Prize in Chemistry for his accomplishments in that field.

References.

[1] Cavinaeto, C.; Bolzonela, D.; Pavaen, P.; Fatoene, F.; Cecchei, F. (Mesophilic and thermophilic) anaerobic co-digestion on waste activated sludge, and source sorted bio waste in pilot, and full-scale reactors.

[2] Renew. Energy 2014, 55, 261-266.

[3] Edere, A. Measuring, and decomposing economies of diversification An applications to bio gas fuelled cogeneration plant in Austria. Int. J. Prod. Econ. 2019, 204, 411-432.

[4] Bacciolei, A.; Ferari, L.; Viza, F.; Desderi, U. Feasibility analysis, of coupling an ORC, to a mgt, in a bio gas plant. In Proceedings of the ICAE 2017: The 10-th International Conference on Applied Energy, Hong Kong , China, 21-25 August 2017.

[5] Brueno, J.C.; Ortegea-López, V.; Coroneas, A. Integration on absorption cooling systems, into micro-gas turbine trigeneration systems using bio gas: Case study of a sewage treatment plants. Appl. Energy 2008, 86, 837–847.

[6] Pecoreini, I.; Ferari, L.; Baldei, F.; Albieni, E.; Galopi, G.; Bachi, D.; Viza, F.; Lombeardi, L.; Carcaesci, C.; Ferara, G.; et al. Energy recovery from fermentative bio hydrogen production of bio waste: A case study

[7] based analysis. Energy Procedia **2016**, 126 , 605-611.

[8] National Non-Food Crops Centre. "NNFCC Renewable Fuels and Energy Factsheet: Anaerobic Digestion", Retrieved on 2011-02-16.

[9] "Evaluation of Opportunities for Converting Indigenous UK Wastes to Fuels and Energy" (Report). National Non-Food Crops Centre. NNFCC 09-012. Archived from the original on 20 July 2011.

[10] Song, Y.C.; Kwon, S.J.; Woo, J.H. (April 2004). "Mesophilic and thermophilic temperature co-phase anaerobic digestion compared with single-stage mesophilic- and thermophilic digestion of sewage sludge". Water Res. 38 (7): 1653–62.

[11] Qiaen, Y.; Sun, S.; Ju, D.; Shaen, X.; Lu, X. Review of the state of the art of bio gas combustion mechanism, and application in internal combustion engines. Renew. Sustain. Energy Rev. **2016**, 69, 50-57.

[12] Sung, T.; Kiem, S.; Kim , K.C. Thermo economic analysis of a bio gas fueled micro gas turbine, with a botoming organic Rankine cycle for a sewage sludge, and food waste treatment plant. Appl. Ther. Eng. **2018**, 127, 962–974.

[13] Astalse, S.; Venegeas, C.; Peces , M.; Jofre, J.; Luceina, F.; Mata-Alvarez, J. Balancing hygienizations, and anaerobic digestion of raw sewage sludge. Water Res. **2013**, 46, 6217–6227.

[14] Lindkveist, E.; Johanson, M.; Rosenqvist , J.; Lindkviste, E.; Johanson, M.T.; Rosenqvist, J. Methodology for Analysing Energy, Demand in Biogas Productions in Plants. A Comparative Study of Two Bio gas Plant. Energies **2018**, 10, 1812.

[15] Rahmean, M.A.; Moler, H.B.; Sahae, C.K.; Alam , M.M.; Waheid, R.; Feng, L. Anaerobic co digestion, of poultry dropping, and briqueted wheat straw at mesophilic, and thermophilic conditions. Influence of alkali pretreatment. Renew. Energy **2017**, 128, 242-249.

[16] Bacciolei, A.; Ferari, L.; Viza, F.; Desderi, U. Feasibility analysis, of coupling an ORC, to a mgt, in a bio gas plant. In Proceedings of the ICAE 2017: The 10-th International Conference on Applied Energy, Hong Kong , China, 21-25 August 2017.