زانكۆی سەلاحەدین - هەولێر
Salahaddin University-Erbil

Biogas Generation from Kitchen Waste

Research Project

Submitted to the Department of (Chemistry) in partial fulfillment of the requirements for the degree of **BSc.** in **chemistry**

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*To begin with, I thank (**Allah**) for His blessing, which made me able to complete and perform this study with success, the lord of the universe, blessing, and peace be on **Muhammad** (Allah's peace and prayers be upon him).*

Finally, I want to say thanks to my Supervisor Dr. Suad and all those who assisted me even by one useful scientific word directly or indirectly.

Supervisor recommendation

I am the student's supervisor, -----student full name----Sara Essa Rasul---. I support that the student has completed all the requirements for submitting the research drawn entitled --title of project-- Biogas generation from kitchen waste -- according to the numbered administrative order 3/1/5/1972 on 9th oct. 2022 in accordance with the instructions of Salahaddin university quality assurance and it is ready for discussion.

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Abstract

Biogas is a versatile fuel as it generates less greenhouse gas emission, it is renewable as it is generated from renewable sources, and its production can be used to treat and reduce the organic waste quantity for disposal while disinfecting pathogens in biomass and has a wide portfolio of energy applications in electricity, heat, and cooling applications.

Anaerobic Digestion of kitchen wastes is a biological process, which takes place in an oxygen-free environment. The process consists of four steps and is carried out by different Groups of bacteria. Some important factors, which influence the climate in which the bacteria have to do their "job," have been explained.

Keyword: biogas, renewable, anaerobic digestion, kitchen waste, methane, fertilizer,

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1. Introduction

Biogas is distinct from other renewable energies because of its characteristics of using, controlling and collecting organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Biogas does not have any geographical limitations nor does it requires advanced technology for producing energy, also it is very simple to use and apply. Due to scarcity of petroleum and coal it threatens supply of fuel throughout the world also problem of their combustion led to research in different corners to get access the new sources of energy, like renewable energy resources. Solar energy, wind energy, different thermal and hydro sources of energy, biogas are all renewable energy resources. Deforestation is a very big problem in developing countries like India, most of the part depends on charcoal and fuel-wood for fuel supply which requires cutting of forest. Also, due to deforestation it leads to decrease the fertility of land by soil erosion. Use of dung, firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution.

We need an ecofriendly substitute for energy. Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that’s why efficiency of methane production can be increased by several order of magnitude as said earlier. It means higher efficiency and size of reactor and cost of biogas production is reduced. Also in most of cities and places, kitchen waste is disposed in landfill or discarded which causes the public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming. Mankind can tackle this problem(threat) successfully with the help of methane, however till now we have not been benefited, because of ignorance of basic sciences – like output of work is dependent on energy available for doing that work. This fact can be seen in current practices of 9 using low calorific inputs like cattle dung, distillery effluent, municipal solid waste (MSW) or sewage, in biogas plants, making methane generation highly inefficient. We can make this system extremely efficient by using kitchen waste/food wastes. (Vij 2011)

(Agrahari and Tiwari 2013) developed a compact biogas system that uses starchy or sugary feedstock material and the analysis shows that this new system is 800 times more efficient than conventional biogas plants.   The proper disposal of NIT ROURKELA's Hostel kitchen waste will be done in ecofriendly and cost effective way. While calculating the cost effectiveness of waste disposal we have to think more than monitory prospects. The dumping of food in places and making the places unhygienic can be taken good care of. It adds to the value of such Biogas plants. Using the natural processes like microorganisms kitchen waste & biodegradable waste viz paper, pulp can be utilized Anaerobic digestion is controlled biological degradation process which allows efficient capturing & utilization of biogas (approx. 60% methane and 40% carbon dioxide) for energy generation. Anaerobic digestion of food waste is achievable but different types, composition of food waste results in varying degrees of methane yields, and thus the effects of mixing various types of food waste and their proportions should be determined on case by case basis.

Anaerobic digestion (AD) is a promising method to treat the kitchen wastes. While Anaerobic digestion for treatment of animal dung is common in rural parts of developing countries, information on technical and operational feasibilities of the treatment of organic solid waste is limited in those parts. There are many factors affecting the design and performance of anaerobic digestion. Some are related to feedstock characteristics, design of reactors and operation conditions in real time. Physical and chemical characteristics of the organic wastes are important for designing and operating digesters, because they affect the biogas production and process stability during anaerobic digestion. They include, moisture content, volatile solids, nutrient 10 contents, particle size, & biodegradability. The biodegradability of a feed is indicated by biogas production or methane yield and percentage of solids (total solids or total volatile solids) that are destroyed in the anaerobic digestion. The biogas or methane yield is measured by the amount of biogas or methane that can be produced per unit of volatile solids contained in the feedstock after subjecting it to anaerobic digestion for a sufficient amount of time under a given temperature which is taken to be laboratory temperature in our case. In recent times varied technological modifications and improvements have been introduced to diminish the costs for the production of biogas. Different Methods have been developed to increase speed of fermentation for the bacteria gas producers, reduction of the size of the reactors, the use of starchy, sugary materials for their production, the modification of the feeding materials for fermentation and the exit of the effluent for their better employment, as well as compaction of the equipment to produce gas in small places like back-yard, among others. Larger facilities operating costs can be reduced, per unit, to the point that, in the current economic framework, very large Anaerobic Digestion facilities can be profitable whereas small ones are not this is what is Economics of scale. If energy prices continue to rise and the demand for local waste treatment, and fertilizers increases, this framework may change (Agrahari and Tiwari 2013, Ogur and Mbatia 2013, Surendra, Takara et al. 2014)

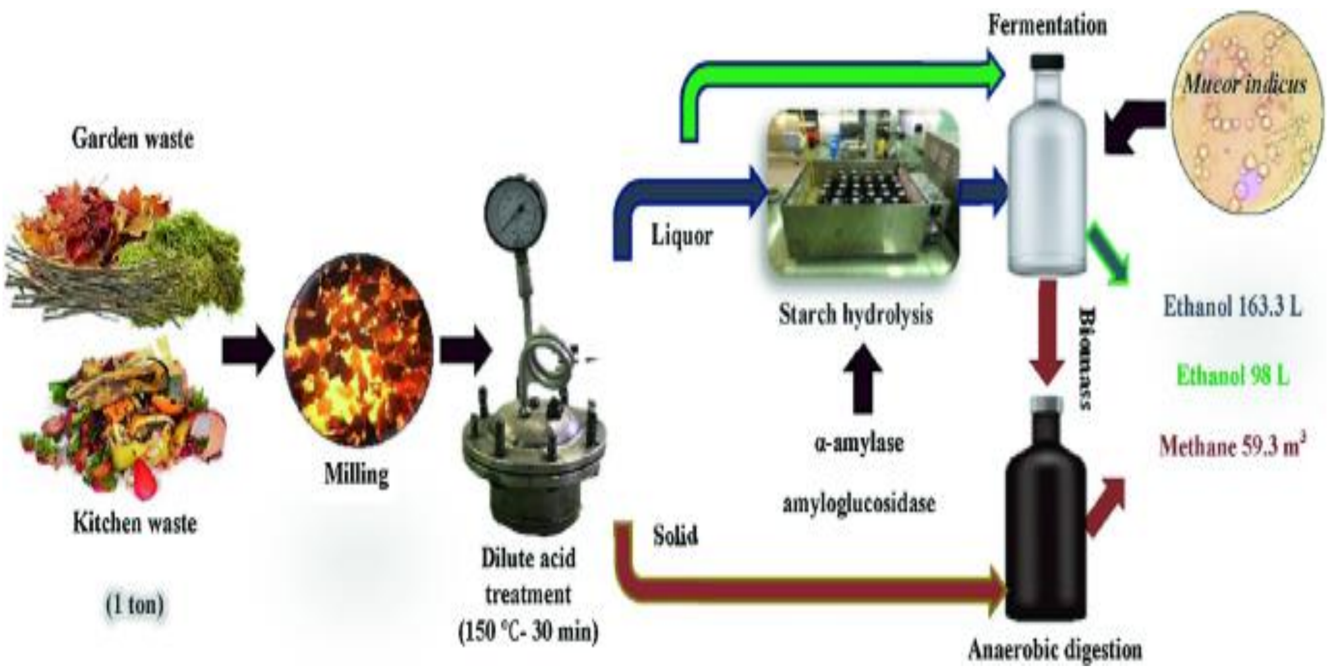

***Fig.1.** The conversion of food waste and sludge into biogas via anaerobic digestion technology*

1.2. Characteristic of Biogas

Composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in range of 650 to 750 0C.An odorless & colorless gas that burns with blue flame similar to LPG gas. Its caloric value is 20 Mega Joules (MJ) /m3 and it usually burns with 60 % efficiency in a conventional biogas stove. This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel, & electricity, depending on the nature of the task, and local supply conditions and constraints. Biogas digester systems provides a residue organic waste, after its anaerobic digestion(AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse (residuals).

TABLE 1:- Composition of biogas.

GENERAL FEATURES OF BIOGAS	
Energy Content	6-6.5 kWh/m3
Fuel Equivalent	0.6-0.65 l oil/m3
Biogas Explosion Limits	6-12 % biogas in air
Ignition Temperature	650-750 *
Critical Pressure	75-89 bar
Critical temperature	-82.5 *C
Normal Density	1.2 kg/m3
Smell	Bad eggs

2. Principles for Production of Biogas

Organic substances exist in wide variety from living beings to dead organisms. Organic matters are composed of Carbon (C), combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins & lipids. In nature MOs (microorganisms), through digestion process breaks the complex carbon into smaller substances.

There are 2 types of digestion process:

- Aerobic digestion.
- Anaerobic digestion.

The digestion process occurring in presence of Oxygen is called Aerobic digestion and produces mixtures of gases having carbon dioxide (CO2), one of the main "green houses" responsible for global warming. The digestion process occurring without (absence) oxygen is called Anaerobic digestion which generates mixtures of gases. The gas produced which is mainly methane produces 5200-5800 KJ/m3 which when burned at normal room temperature and presents a viable environmentally friendly energy source to replace fossil fuels (non-renewable). (Holm-Nielsen, Al Seadi et al. 2009, Dhanalakshmi and Ramanujam 2012) .

2.1 Anaerobic Digestion

It is also referred to as biomethanization, is a natural process that takes place in absence of air (oxygen). It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutrias effluents.

BIOLOGICAL PROCESS (MICROBIOLOGY)

1. Hydrolysis
2. Acidification
3. Methanogenesis

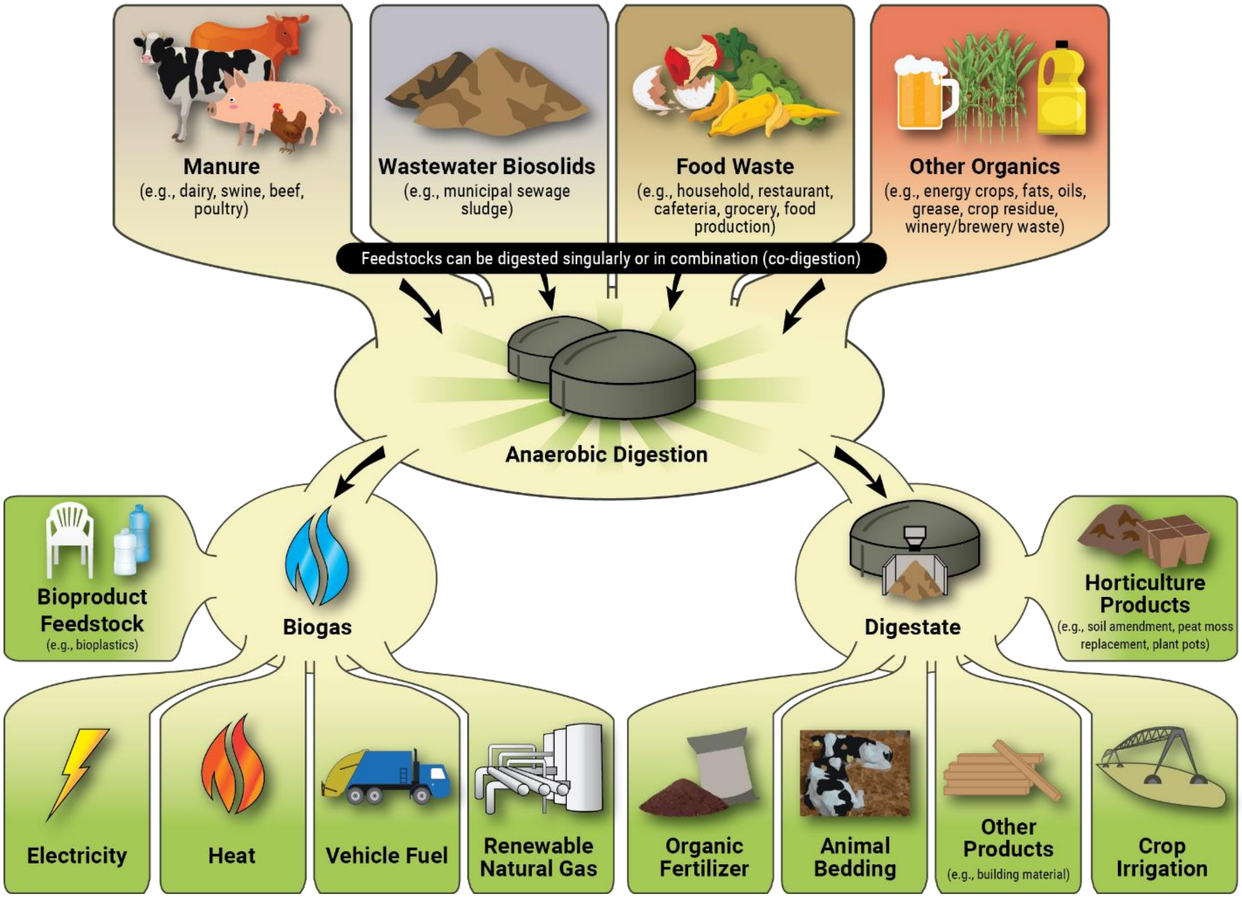

Fig2. The following figure illustrates the flow of feedstocks through the AD system to produce biogas and digestate.

2.2 Hydrolysis:

In the first step the organic matter is enzymolysed externally by extracellular enzymes, cellulose, amylase, protease & lipase, of microorganisms. Bacteria decompose long chains of complex carbohydrates, proteins, & lipids into small chains. For example, Polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

2.3 Acidification

Acid-producing bacteria, involved this step, convert the intermediates of fermenting bacteria into acetic acid, hydrogen and carbon dioxide. These bacteria are anaerobic and can grow under acidic conditions. To produce acetic acid, they need oxygen and carbon. For this, they use dissolved O2 or bounded-oxygen. Hereby, the acid-producing bacteria creates anaerobic condition which is essential for the methane producing microorganisms. Also, they reduce the compounds with low molecular weights into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical point, this process is partially endergonic (i.e., only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction. (Vindis, Mursec et al. 2009, Herout, Malaťák et al. 2011).(Vindis, Mursec et al. 2009, Herout, Malaťák et al. 2011)

2.4 Methanogenesis

(Methane formation) Methane-producing bacteria, which were involved in the third step, decompose compounds having low molecular weight. They utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, CH4 producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), and in marshes. They are basically anaerobic and very sensitive to environmental changes, if any occurs. The methanogenic bacteria belong to the archaebacteria genus, i.e. to a group of bacteria with heterogeneous morphology and lot of common biochemical and molecular-biological properties that distinguishes them from other bacteria's. The main difference lies in the makeup of the bacteria's cell walls. (Islam, Salam et al. 2009, Voegeli, Lohri et al. 2009)

2.5. Symbiosis of Bacteria:

Methane and acid-producing bacteria act in a symbiotical way. Acid producing bacteria create an atmosphere with ideal parameters for methane producing bacteria (anaerobic conditions, compounds with a low molecular weight). On the other hand, methane-producing microorganisms use the intermediates of the acid producing bacteria. Without consuming them, toxic conditions for the acid-producing microorganisms would develop. In real time fermentation processes the metabolic actions of various bacteria acts in a design. No single bacteria is able to produce fermentation products alone as it requires others too.

3. Biogas Production from Kitchen Wastes:

Biogas is produced out of kitchen wastes through a biological phenomenon called anaerobic digestion. Anaerobic means that the process takes place in an oxygen-free environment. The kitchen wastes in the substrates are reduced and converted to biogas by micro-organisms.(Bond and Templeton 2011, Lindeboom, Fermoso et al. 2011)

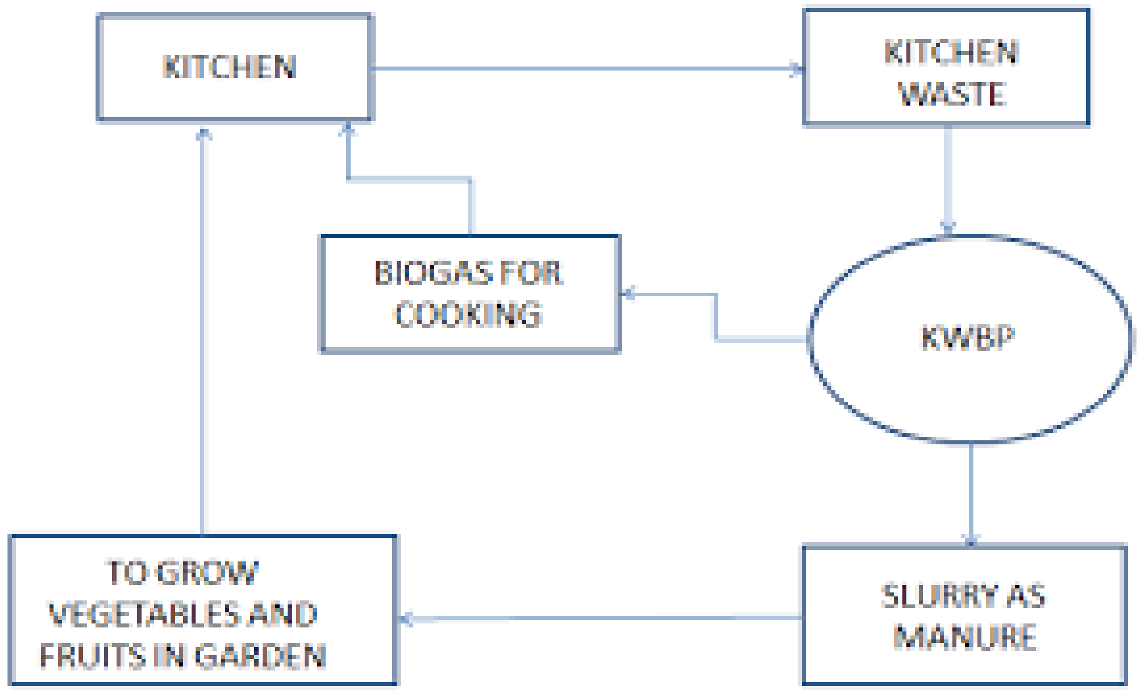

Fig 3: Flow diagram of Biogas production from kitchen wastes & its use.

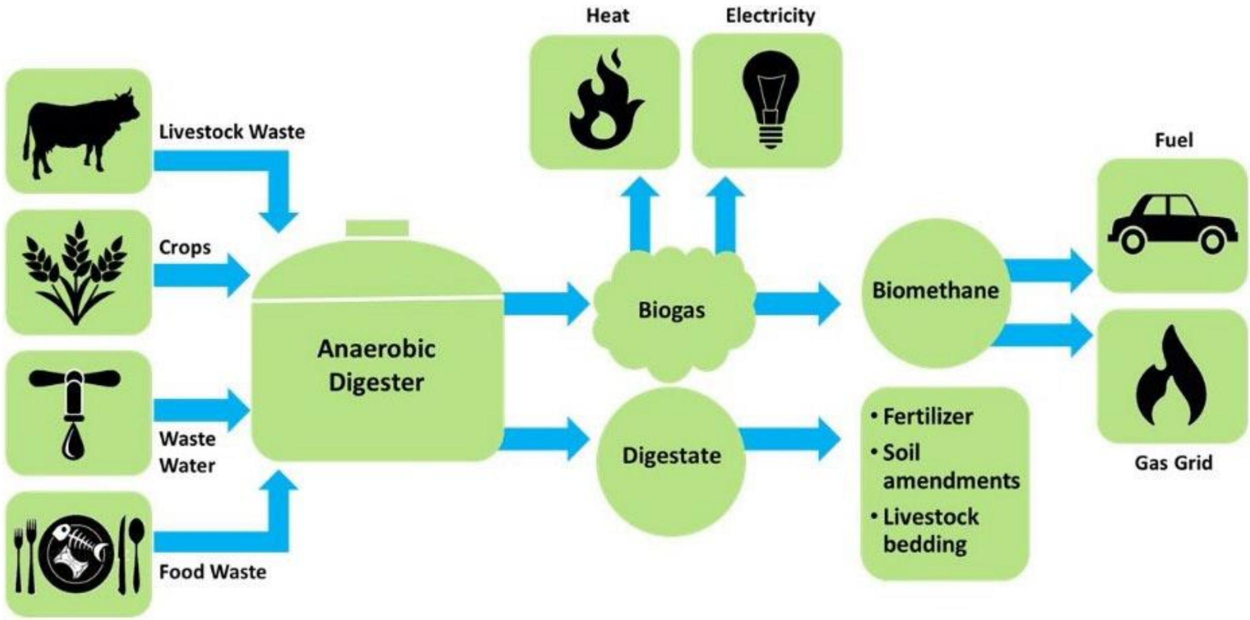

Fig 4. Flow chart for biogas production and converting waste to energy

3.1. Four Phases of Digestion of Kitchen Wastes

The process consists of four steps, each of which carried out by different groups of bacteria:

i. Hydrolysis.

ii. Acidogenesis.

iii. Acetogenesis.

iv. Methanogenesis.

3.1.1. Hydrolysis

In general, hydrolysis is a chemical reaction in which the breakdown of water occurs to form H+ cations and OH- anions. Hydrolysis is often used to break down larger polymers, often in the presence of an acidic catalyst. In anaerobic digestion, hydrolysis is the essential first step,

as Biomass is normally comprised of very large organic polymers, which are otherwise unusable. Through hydrolysis, these large polymers, namely proteins, fats and carbohydrates, are broken down into smaller molecules such as amino acids, fatty acids, and simple sugars. While some of the products of hydrolysis, including hydrogen and acetate, may be used by methanogens later in the anaerobic digestion process, the majority of the molecules, which are still relatively large, must be further broken down in the process of acidogenesis so that they may be used to create methane.

3.1.2. Acidogenesis:

Acidogenesis is the next step of anaerobic digestion in which acidogenic microorganisms further break down the Kitchen wastes after hydrolysis. These fermentative bacteria produce an acidic environment in the digestive tank while creating ammonia, H_2, CO_2, H_2S, shorter volatile fatty acids, carbonic acids, alcohols, as well as trace amounts of other by-products. While acidogenic bacteria further breaks down the organic matter, it is still too large and unusable for the ultimate goal of methane production, so the biomass must next undergo the process of acetogenesis.

3.1.3. Acetogenesis:

In general, acetogenesis is the creation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. These microorganisms catabolize many of the products created in acidogenesis into acetic acid, CO_2 and H_2. Acetogens break down the kitchen wastes to a point to which Methanogens can utilize much of the remaining material to create Methane as a Biogas.

3.1.4. Methanogenesis:

Methanogenesis constitutes the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. There are two general pathways involving the use of acetic acid and carbon dioxide, the two main products of the first three steps of anaerobic digestion, to create methane in methanogenesis: (Gargiulo and Benassi 2000)

$CO2 + 4\ H2 \rightarrow CH4 + 2H2O2$

$CH3COOH \rightarrow CH4 + CO2$

While CO2 can be converted into methane and water through the reaction, the main mechanism to create methane in methanogenesis is the path involving acetic acid. This path creates methane and CO2, the two main products of anaerobic digestion. This is the final stage of digestion results in methane production. Ninety per cent of the total amount of methane is formed during this phase. Also CO2 is released and, in small proportions, also water, H2S and N2. The content of methane in biogas typically varies between 50% and 60%.

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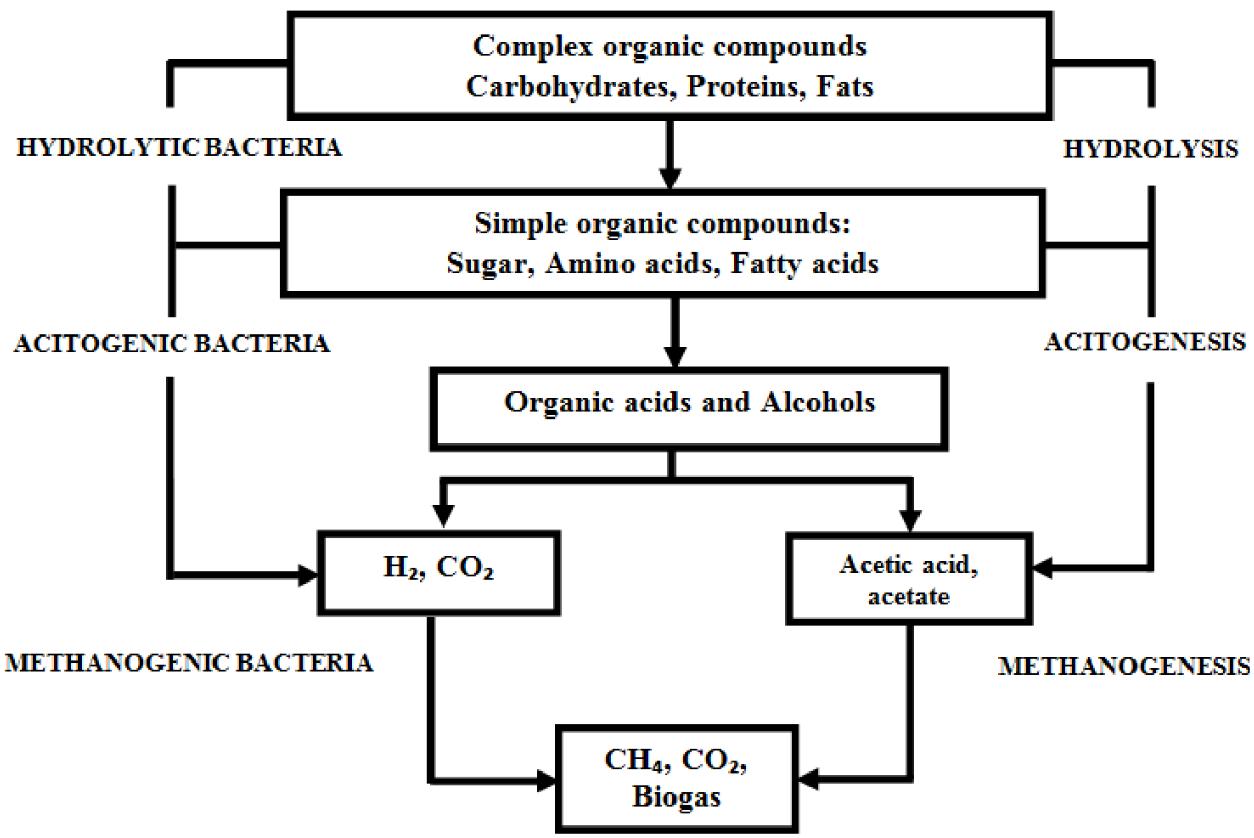

Fig 5. Flow chart showing the four phases of kitchen waste digestion

4. Environmental Conditions for Bacteria

The bacteria are sensitive to temperature. For that reason, the temperature of the fermenter has to be kept at a certain level in order to prevent the bacteria from being killed. In practice, a division is made between mesophilic bacteria and thermophilic bacteria. Mesophilic bacteria require temperature between 25°C and 45°C, typically approximately 38°C. For thermophilic bacteria, temperature of 45°C or more is required. Thermophilic bacteria are more sensitive to temperature changes than mesophilic bacteria. For that reason, thermophilic digestion is more difficult to control. Apart from a certain constant temperature, there are more factors which have a positive influence on the climate for bacteria (Setyobudi, Yandri et al. 2021)

4.1. A Humid Environment

The water content of the substrate should be at least 50% for the methane building bacteria to work and to reproduce themselves.

4.2. A Dark Environment

Although light is no lethal for the bacteria, it does slow the process down. So creating a dark environment supports the digestion process.

4.3. The pH-Value in The Digester

Generally, each bacteria colony operates optimally at a certain pH-level. For the methanogens, this is 7. In case of single-stage digestion, where just one fermenter is used, it is recommended to maintain this pH-level. To build up cell material, bacteria need nutrients, vitamins and minerals. Manure generally provides sufficient nutrients, vitamins and minerals. (Rao, Baral et al. 2010)

4.4. Large Surface of Substrates

The finer the substrates are when they enter the fermenter, the larger the specific surface area, and the better the digestion process will develop. Especially when the retention time is short, it is important to use a very fine grind of the substrates. (Bajracharya, Dhungana et al. 2009)

4.5. Continuous Feed of Substrates

To prevent the bacteria from being overfed, it is important to create a substrate flow which is as continuous as possible. The better degradable the substrates are, the more often they have to be fed in the fermenter tank.

4.6. Gas Outlet

The easier the biogas can escape from the substrate, the higher the production will be. To accomplish that, the gas pressure above the substrates should not become too high. A good gas outlet is therefore necessary.

4.7. Avoidance of Disturbing Substances

Some substances have a disturbing or even devastating effect on the biogas production. Oxygen is a good example, but also antibiotics or moldy substrates can disturb the digestion process. (Kubaska, Sedlacek et al. 2010)

5. Process Parameters

There are three main parameters which describe the digestion process. These are:

5.1. Loading

This represents how many kilograms of kitchen wastes per m3 fermenter volume per day are being fed into the digester.

5.2. Retention Time

The so called hydraulic retention time is the theoretical duration that the substrate stays in the fermenter. For a continuously stirred vertical fermenter, this is a calculated value. For a plug flow fermenter, the hydraulic retention time represents the actual retention time quite accurately. Generally, the easier a substrate can be broken down, the shorter the hydraulic retention time can be.

5.3. Degradation Percentage:

This reflects the percentage of the total amount of kitchen wastes which are broken down during the retention time. Typically, this is approximately 60%. More is possible, but one would require a considerably longer retention time. (Cavenati, Grande et al. 2005)

6. Biogas Installation for Kitchen Wastes:

Kitchen wastes have high moisture content (typically >70%moisture) and weak structure. Thus, it tends to slump, become anaerobic and putrid if stored. Frequently, it is attractive to birds, animals and insects (crows, rats, foxes, flies, etc.), which can be vectors for spreading disease. Biogas installations for kitchen wastes come in different shapes and sizes. We can opt for a batch process or for a continuous process. We can choose a vertical or horizontal digester, single stage or multi stage, mesophilic or thermophilic etc. Most biogas installations operate continuously. In practice, that means that kitchen wastes are fed in the digester several times a day. Digestate is taken out of the digester concurrently.

The content of the digester is constant, which results in a smooth and continuous biogas production. The loading of kitchen wastes are well controllable; the feeding installation can easily be automated.

In many cases, two or more digester tanks are applied: multi-stage digestion. What happens a lot is that the digestate from the main digester is stored in a second digester tank, which also serves as digestate storage facility. This way, more biogas production is achieved. (Paolini, Petracchini et al. 2018)

7. Applications of Biogas:

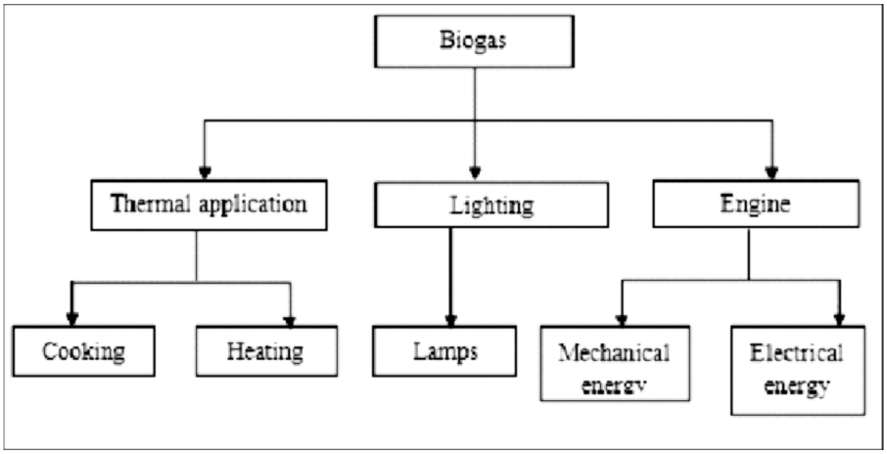

***Fig.6*. Bio gas applications**

The Top Applications (or Uses to which Biogas is Applied) of Biogas are:

1. Electricity generation
2. In combined heat and power (CHP) plants
3. Waste Management in agriculture
4. Cooking fuel as a sustainable energy source
5. Injection into a natural gas pipeline
6. As a Clean Renewable Fuel for Transport Vehicles
7. In Biogas Fuel Cells

7.1. Electricity Generation:

The application of biogas to electricity generation is the most common of all uses. Biogas made from plant material offers a renewable way to generate electricity. Unlike solar power available only during the day or wind power made only intermittently, biogas uses a reliable field crop grown and harvested by farmers.

Biogas possesses chemical energy, and therefore electricity from biogas comes as a result of converting this chemical energy to mechanical energy and finally into electricity. This is done by the use of transducers such as generators and turbines that convert energy from one form to another. This electricity can be used both domestically and commercially since it can be made in small and large scale. Connect the biogas source to the inlet of the gas engine. The biogas source may be a cylinder that contains pressurized gas or directly from a digester, which is the means of decomposing the organic material. The gas engine is designed to work in a similar manner to that of a car, since it is composed of pistons within which the gas is burnt and used to rotate a shaft, converting the chemical energy in the biogas into mechanical energy through motion. Connect the gas engine to the AC generator in such a way that the rotating shaft powers the AC generator. The motion transferred to the AC generator produces electricity through magnetism.

7.2. In Combined Heat and Power (CHP) Plants:

The application of biogas to produce combined heat and power should be as common as electricity generation, but the additional CHP plant requires additional investment, so the add-on equipment needed to use the waste heat may not be installed. Whenever that happens it should be seen as a missed opportunity. There is almost always a use to which the heat can be put, from electricity generation. Energy which would otherwise have to be wasted to the air around the cooling fans.

The valuable component of biogas is methane (CH_4) which typically makes up 60%, with the balance being carbon dioxide (CO_2) and small percentages of other gases. The proportion of methane depends on the feedstock and the efficiency of the process, with the range for methane content being 40% to 70%. Biogas is saturated and contains H_2S, and the simplest use is in a boiler to produce hot water or steam.

The most common use is where the biogas fuels an internal combustion gas engine in a Combined Heat and Power (CHP) unit to produce electricity and heat. In Sweden the compressed gas is used as a vehicle fuel and there are a number of biogas filling stations for cars and buses. The gas can also be upgraded and used in gas supply networks. The use of biogas in solid oxide fuel cells is also being researched. Biogas can be combusted directly to produce heat. In this case, there is no need to scrub the hydrogen sulphide in the biogas. Usually the process utilize dual-fuel burner and the conversion efficiency is 80 to 90%. The main components of the system are anaerobic digester, biogas holder, pressure switch, booster fan, solenoid valve, dual fuel burner and combustion air blower.

7.3. Waste Management in Agriculture:

After energy we rate the next most important application of biogas is for agricultural (livestock) waste management. Crop residues and manure can be digested either alone or in co-digestion with other materials, employing either wet or dry processes. In the agricultural sector one possible solution to processing crop biomass is co-digested together with animal manures, the largest agricultural waste stream. In addition to the production of renewable energy, controlled anaerobic digestion of animal manures reduces emissions of greenhouse gases, nitrogen and odour from manure management, and intensifies the recycling of nutrients within agriculture. Co digestion offers good opportunity to farmers to treat their own waste together with other organic substrates. As a result, farmers can treat their own residues properly and also generate additional revenues by treating and managing organic waste from other sources and by selling and/or using the products viz heat, electrical power and stabilized fertilization.

According to the government's Chinese Ecological White Paper issued in 2002, the total amount of livestock and poultry wastes generated in the country reached 2.485 billion tonnes in 1995, some 3.9 times the total industrial solid wastes. This illustrates just how big an issue agricultural waste is. These wastes are precious resources if used properly, but constitute major pollution when discharged directly into rivers and lakes. It is estimated that less than 10 percent of the wastewater in China is currently treated, and that 10 million ha of farmland are seriously polluted by organic wastewater and solid wastes as well. It is true that farmers continually recycle their livestock waste by simply spraying it onto the fields, but it is far more hygienically done with less odour, lower pollution risk, and much better availability of nutrients, after first going through anaerobic digestion. Jonathan Letches notes in his book, “Farm Digesters” that only about half of the nitrogen present in livestock waste when ordinarily untreated and spread as “muck” onto fields is available for plant uptake. The rest is organic nitrogen still held in the fibrous material in cells yet to degrade. It generally takes a years or more before that 50% of the waste material breaks down by the action of bacteria in the ground, and can be used by the growing crop. On the other hand, if the livestock waste first goes through an anaerobic digester, the bacteria convert the organic nitrogen present in the manure or slurry into nitrates. This is the form in which it can easily be adsorbed by plants. Furthermore, good farm management which ensures that the digester output, “digestate“, is spread during the growing season, can mean that the farm's nutrients can be much more efficiently used when the farm has an operational biogas plant.

Observers of crops which are fertilized with digestate frequently comment that the crop not only grows well, but it also looks much healthier. Darker greens are noticed, and fewer damage takes place from pests and disease. Many attributes these benefits of biogas plant fertilizer to the rise in healthy bacteria and other micro-organisms in the soil after regular application of digestate. Farmers which run their own digesters have reported that their need for expensive chemical fertilizer reduces by at a third to half, after commencing use of digestate fertilizer. This can amount on a good-sized farm to a third of a million GBP saving ($400,000) annually. (Kabeyi 2020)

7.4. Biogas Applied to Use as a Cooking Fuel – A Sustainable Energy source:

The application of biogas for cooking and baking is a promising option for improving the energy supply of the poor, i.e. over 2.7 billion people who rely on the inefficient and unhealthy burning of biomass as main energy source. Provided the biogas is properly combusted, biogas stoves produce the lowest level of greenhouse gas emissions compared to other technologies that use fuel combustion, e.g., biomass or fossil fuels. In this context, biogas stoves may help to reduce the impact on climate change of cooking practices in rural areas. Stoves and ovens using biogas have the potential to improve the wellbeing of marginalized people. They offer an excellent opportunity to put an end to the indoor pollution generated in the kitchens of many poor families around the world, as well as treating organic waste that commonly represent health and environmental threats. This can have positive impacts on the vicious cycle of poverty. However, biogas solutions for cooking depend (in the first instance) on the technical feasibility of users producing their own fuel (biogas). Thus, broad diffusion of the technology as an application of biogas requires thorough assessment of potentials and requirements of potential users.

The production of fuel wood and charcoal has resulted in deforestation and soil erosion in some regions. Increasing population and declining wood resources will further worsen the situation. One cubic meter of biogas can replace 5.6kg firewood and 1.7kg charcoal. Additionally, the by-product of biogas production (the digestates) can be directly used as fertilizer or for the production of humus (e.g. cooking with biogas where possible)) can significantly reduce deforestation and help to mitigate soil depletion. However, these advantages for the application of biogas depend on the quality of the biogas stove (particularly the burner).

Partial combustion results in a considerable portion of the methane contained in biogas being released un-burnt into the atmosphere. Methane is 20 to 60 times more powerful than carbon dioxide in causing climate change. Partial combustion of biogas also results in a high content of toxic carbon monoxide in the exhaust gases. In households that use biogas for cooking, people may benefit in terms of their wellbeing (e.g. from better indoor air quality and time and cost savings). However, assuring the long-term adoption of the technology has proved difficult in many cases. However, untended systems and dissatisfied users have negatively influenced the uptake of the technology in many areas. Integrating the application of biogas into the daily practices of users appears to be an indispensable condition (and also a complex challenge) in ensuring the sustainable use (and diffusion) of the technology.

The switch to biogas in cooking is not without challenges. According to the IEA, with an increase in income, households do not simply switch from one fuel to another after the application of biogas. The use of multiple fuels in parallel may enhance energy security compared to reliance on a single fuel or technology. Besides, traditional food preparation processes are not easily being overhauled because of taste preferences and the familiarity of cooking with traditional technologies. Nevertheless, in the long run and on a regional scale, households in countries that become wealthier are generally projected to shift from cooking exclusively with biomass to using more efficient technologies, among which biogas can be one option (IEA, 2006, 2008). Currently, low per-capita incomes and a lack of awareness of the benefits of more sustainable fuels provides an important barrier to the wholesale application of biogas. Therefore, financing investments in biogas installations, especially in least developed countries, is a problem. Hence, financing programmes and additional incentives are clearly needed to deal with this general reluctance among the target group. In India, for example, many of the the application of biogas plants is concentrated on wealthier farms with a relatively large number of cattle).

7.5. Injection Into a Natural Gas Pipeline:

To understand the application of biogas as a fuel added into fossil fuel natural gas supply pipelines, needs to be explained. When purified to a suitable extent to be injected in a natural gas pipeline, the pure gas is usually called “biomethane”. Biomethane injected in this way is in demand in many countries where the population is keen to comply with climate change reduction methods. The gas industry calls the compressed biomethane “Renewable Natural Gas” or RNG. The potential for RNG and biomethane in gas applications in the U.S. is virtually untapped. According to figures from the Coalition for Renewable Natural Gas, of more than 1,000 landfills that could be candidates for biogas production, only 42 high-BTU landfill gas-to-energy projects are producing RNG, biomethane, upgraded or pipeline-quality biogas. Of 3,500 potential wastewater treatment plant biogas projects, only 1,200 have operational facilities that are recovering biogas to either generate renewable electric power or provide transportation fuel. Out of more than 12,000 potential agricultural digester projects that could produce biogas, only 239 biogas production facilities are in operation.

Local gas distribution and transmission pipeline companies are increasingly being approached to purchase and/or take delivery of renewable natural gas (RNG) into their existing lines for general distribution. RNG is derived from anaerobic decomposition of a wide variety of organic materials, including dairy and agricultural waste and wastewater and landfill sources. Within the natural gas industry, the term ‘biogases refer to gas produced directly from digesters or landfills; it is often burned on or off-site in generators for conversion to electricity or simply flared. Cleaned biogas or biomethane, more commonly referred to today as RNG, is the target product for inclusion in the natural gas pipeline grid.

Connecting to the grid and moving the RNG from one location to the other come with grid related fees such as injection fees, transportation fees, distributions fees, balancing fees, brokering fees, etc. Nevertheless, the opportunity to move the RNG anywhere it may be needed enables fantastic opportunities to RNG producers. In markets where there is a renewable portfolio standard (RPS), a carbon tax, or a cap and trade system for the reduction of greenhouse gas (GHG) emissions, there is a significant demand for RNG to achieve goals of emission reduction.

7.6 As a Renewal Fuel for Transport Vehicles:

If concentrated and compressed, and ideal application of biogas exists in vehicle transportation. Compressed biogas is becoming widely used in Sweden, Switzerland, and Germany. A biogas-powered train, named Biogas target Amanda (The Biogas Train Amanda), has been in service in Sweden since 2005. Biogas powers automobiles. In 1974, a British documentary film titled *Sweet as a Nut* detailed the biogas production process from pig manure and showed how it fuelled a custom-adapted combustion engine Even as early as 2007, an estimated 12,000 vehicles were being fuelled with upgraded biogas worldwide, mostly in Europe. The big advantage for transport use can be that a fleet of trucks can be fuelled by biogas very efficiently, if the vehicles are fuelled at the same location as the biogas plant. If so, there is no cost for transporting the biogas to the point-of-use. (Pokharel and Chettri 2011, Megwai and Richards 2016, Abokyi, Appiah-Konadu et al. 2018)

7.7. Fuel Cells

Theoretically, biogas can be converted directly into electricity by using a fuel cell. However, this process requires very clean gas and expensive fuel cells. Therefore, this option is still a matter for research and is not currently a practical option. The conversion of biogas to electric power by a generator set is much more practical.

8. Conclusion

Biogas technology is a promising venture globally mainly because of the existence of mature production technologies and applications as well as promising future technologies. Biogas technology is viable and sustainable due to the abundant supply of cheap feedstocks and availability of a wide range of biogas applications in heating, power generation, use as fuel, and raw material for further processing and production of sustainable chemicals including hydrogen and carbon dioxide and biofuels. The flexibility of biogas production in terms of size from small-scale to large-scale industrial size digesters and a wide range of feasible feedstock allows to produce biogas anywhere globally. Biogas production and use is growing globally and is promising to be a leading economical alternative to produce renewable bioenergy.

Biogas is a versatile fuel as it generates less greenhouse gas emission, it is renewable as it is generated from renewable sources, and its production can be used to treat and reduce the organic waste quantity for disposal while disinfecting pathogens in biomass and has a wide portfolio of energy applications in electricity, heat, and cooling applications. Biogas yield from biomass can be increased by appropriate pre-treatment of the substrate and monitoring of digestion parameters like C/N ratio, temperature, and substrate dilution. Various biogas to many electricity conversion technologies is available, but trigeneration and combined heat and power show higher conversion efficiencies while fuel cells have the highest level of system reliability. On the environmental sustainability of the energy transition, biogas use reduces global greenhouse gas emissions and the threat of global warming and climate change. Biogas use helps keep the environment clean by preventing harmful environmental and health impact from the huge agricultural wastes available globally. Therefore, biogas provides financial, economic, environmental, and health benefits for the critical mass of humanity who rely on agriculture for subsistence as well as cash Bio methanation or conversion of biogas to biomethane is another pathway for direct use in heat and power generation as a fuel which can be injected to natural gas pipeline as renewable gas. Biogas engines are made by modification of the conventional compression ignition and spark ignition engines. Full and partial conversion can be done. Other fuels with potential for production from biogas are hydrogen, ME, and FT diesel but not yet at commercial scales .This study showed that it is feasible to generate biogas from kitchen waste using

Anaerobic Digestion of kitchen wastes is a biological process, which takes place in an oxygen-free environment. The process consists of four steps and is carried out by different Groups of bacteria. Some important factors, which influence the climate in which the bacteria have to do their "job," have been explained.

The three main parameters which describe the digestion process have been identified. Based on the presented information, we will be able to gain some more insight in the different possibilities and components for biogas installation for kitchen wastes. The choice on the final means for the application of biogas, impacts the design and equipment requirements for biogas processing, storage and the economics of the biogas conversion system. The biogas may be applied in direct combustion systems (boilers, turbines, or fuel cells) for producing space heating, water heating, drying, absorption cooling, and steam production. The gas used directly in gas turbines and fuel cells may produce electricity. An alternative choice in biogas conversion is the use in stationary or mobile internal combustion engines which results in shaft horsepower, co-generation of electricity, and/or vehicular transportation. A final opportunity exists for sale of the biogas through injection into a natural gas pipeline.

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