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A Review on Different Methods to Generate Biogas

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ABSTRACT

In the discussion of biogas and biomass the focus is mainly on, generation of bio-energy by adopting any one method, integrated generation system and estimating bio-energy potential of a particular location. This paper highlights the different methods of biogas generation. Further the stress is given on classification and basic concepts related to different bio-technological and bio-chemical methods used for the generation of biogas and the biomass material. The understanding of bio-technological and bio-chemical methods is important for adopting it according to the type, availability, accessibility of biomass material, suitability and other advantages to that place. The proper adoption of method can lead to increase proper utilization of biomass material, gain more biogas, increase efficiency of adopted method and reduce pollution and waste. The waste of biomass can further be utilized for other applications. After studying various bio-technological and bio-chemical methods it was found that for bio-energy generation adoption of proper method is important. It is concluded that an anaerobic process is the most suitable process in terms of availability and accessibility of biomass material and ease of operation and maintenance.

Keywords: *Combined Heat and Power (CHP); Municipal Garbage Waste (MGW); Municipal Solid Waste (MSW); Livestock Waste*.

1. INTRODUCTION

Energy is the most important material for economic development, social progress and human survival. With global warming and increasing environmental pollution, energy conservation, low-carbon economy and renewable energy are paid more attention around the world. If someone talks about renewable energy, mostly it is about the more familiar forms of renewable energy sources like solar and wind. But biomass is also one of the oldest renewable energy sources. The biomass can supply more renewable energy than wind and solar power. The biomass is more reliable than wind and solar as it is less uncertain as compared to them. So, biomass energy is a good alternative energy which not only releases less harmful gas and pollutants but also could take good use of waste management in Rural and Urban areas. It is a good way to resolve the energy stress, environmental and waste disposal problem [1]. Energy generation from biomass has been categorized as the promising source in the near future. The estimated world biomass production potential is 146 billion tons per annum [2]. To exalt the importance of biomass use research have estimated that the world wide biomass potential could provide 1.4 times the estimated annual 1,50,000 Terra hours needed to meet the present world energy consumption. Globally about $1x10^{11}$ tons of biomass annually generates roughly 25 Terra watts [3].

In the countries and regions such as United States, United Kingdom, Brazil, European Union and Asian countries like Pakistan, Bangladesh and India, where biomass energy has been very successfully developed. It is common that they have rich biomass resources and all take good use of these resources according to their reserves and distribution. If the biomass energy is to be used on large scale it is necessary to analyze the situation of biomass waste. The electricity generation from biomass waste depends on the availability of biomass material resources and technology for conversion of waste to energy. Now this was in the face of increasing legislature on manure storage and disposal [1].

William H. Carlson investigates the relationship of size to power cost for biomass power facilities utilizing traditional waste wood supplies. The analysis here is applicable to forestry waste, agricultural waste and urban waste wood. As all the biomass is local, thus host biomass plant is preferred with combined heat and power (CHP) option as it leads to the optimization of the facility at much smaller size. Because of its public acceptance and availability in industrial and urban setting it is also the perfect renewable fuel for CHP application. Because of these stark differences, it does not necessarily follow that a bigger biomass plant produces cheaper electricity or is more valuable to the utility [4-5].

The post-consumer residues as urban wood and landfill gas already make a significant power contribution in United States, Europe and Japan. The United States supply curve for 2020 shows its approximately 450 million tons potential as well as USA stretch potential for the middle of the century of a Giga tons [6]. In United Kingdom the estimated electrical potential of electricity yield from industrial waste, commercial waste, municipal waste and household waste can supply as much as 17% of the total electricity consumption by 2020 with the implementation of an advance thermal conversion method and with recycling target or techniques [7]. Pakistan has huge potential for power generation from biomass. Every year thousands of tons of biomass is available in the form of sugarcane tress, cotton sticks, dairy waste and municipal waste which can be utilized for power generation in Pakistan. In Pakistan the biomass contribution is 65% of the total power consumption in the

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country [8-9]. Bangladesh has large potential of power generation from biomass of rice husk. The modern study on rice husk waste conducted that there is a potential to produce electricity from rice husk, which is abundantly available in large amount in Bangladesh [10-12]. Power generation from rice husk is more efficient and economical than coal. The only requirement for the generation of electricity from rice husk is availability of rice husk and the technology for conversion rice husk to energy. The consumption of rice husk for steam turbine power plant for generation of electricity is 1.3 Kg/kWh as reported by Singh [13] and on the other hand consumption of rice husk for gasification power plant for generation of electricity is 1.86 Kg/kWh by Islam [14]. Based on this assumption the capacity of electric power generation was estimated about 29 to 41 MW and can be installed in Bangladesh [15].

Usage of renewable energy is ever increasing in developing countries like India, which has huge amount of biomass resources like sugarcane, banana, rice husk, pruning, municipal garbage waste (MGW) of Urban and Rural. Annually India generates about 62 million tons of municipal solid waste (MSW) out of which 82% is being collected and the remaining 18% is littered. Out of the total collected waste only 28% is being treated and disposed; remaining 72% or 45 million tons of annually generated is untreated and dumped. It needs 245,000 cubic meter of landfill space every day. Due to urbanization and increased industrialization the population moves towards urban area also due to changes in the life pattern, there is urgent need to look into this subject and find out the way and methods to cope with this extremely fast growing garbage problem.

However, to overcome the growing garbage problem and to earn the benefits from the MGW it is needed to have a proper utilization and management of MGW. The MGW is viable in generating electricity, if it is via-ducted by adopting an advanced technology to recover electrical energy from it as shown in figure 1. This reduces the quantity of MGW and environmental pollution, health and hygienic problem**.**

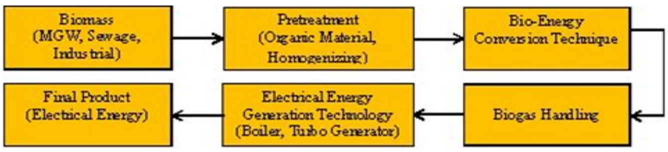

Figure 1. Basic block diagram.

2. COMPONENTS OF MGW

2.1. Primary Residues: Primary residues are a byproduct of the primary product. It is a leftover from the primarily produced product after extraction is done over primarily produced product. The primary residues are agricultural waste after harvesting in the fields like paddy straw, wheat straw, sugarcane top, maize stalks, palm oil frond and bunches, corn stoves, coconut empty branches, forest thinning etc. U.S. focused on the corn stoves as primary residue harvested from primary grain crop [16]. Further processing of primary residues gives secondary and tertiary residue.

2.2. Secondary Residues: Secondary residues or a processed residue is the co-product of primary product. The primary processing of biomass into other products and material give rise to secondary residues. It can also say that a primary process over the primary product give rise to secondary residue. The secondary residues are paddy husk, coconut shell coir dust, palm oil shell, black liquor, process chemicals, sugarcane bagasse etc. are widely used fuel in CHP to produce heat and electricity.

2.3. Tertiary Residues: Tertiary or post-consumer residues are the waste coming out from the consumed primary product or it is a waste after consuming the primary product. The tertiary residues includes dairy waste, human and animal waste, kitchen and Hotel waste, pruning and MGW etc. are now becoming the major raw material of future bio-energy generation system. In urban areas and cities of many countries, tertiary residues are collected under the title of MGW by generating MGW collection sectors. These collected tertiary residues can be utilized for generation of electrical power by combustion facilities as well as from generating methane gas by properly managing the MGW [5]. If the sewage is treated it will produce methane, the rate of residue generated of an individual is of about 22MJ/person/day. Thus combining the residue of a high populated or densely populated metropolitan area, results into very high amount of bio energy potential [17]. Depending upon the moisture content, these tertiary residues are of two types: one is less moisture say wet residue and other is more moisture say watery residue.

3. BIO-ENERGY CONVERSION TECHNOLOGY

The moisture content in biomass decides the conversion technology to be employed. The biomass with dry material, thermal conversion technology is employed. The biomass with less moisture content, thermo chemical

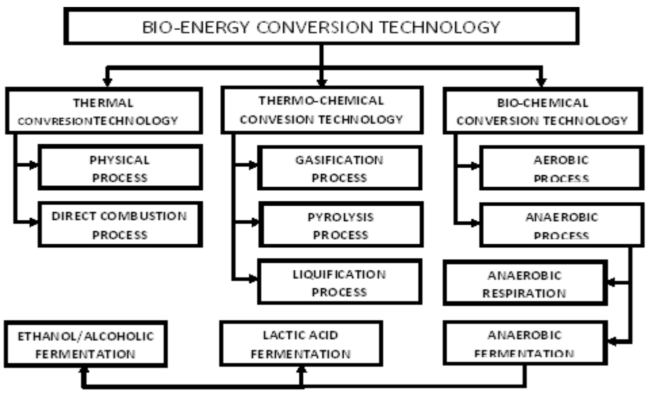

Figure 2 Flow Chart of Bio-Energy Conversion Technology.

conversion technology is employed and if biomass with large moisture content bio-chemical conversion technology is employed. Hence primary, secondary and tertiary residues can

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be consumed by three conversion technologies such as Thermal Conversion Technology (TCT), Thermo-Chemical Conversion Technology (TCCT) and Bio-Chemical Conversion Technology (BCCT). Figure 2 shows the flow chart of Bio Energy Conversion Technologies.

3.1. Thermal Conversion Technology

Thermal conversion technology (TCT) includes physical process for densification and homogenization as well a direct combustion process for thermal power generation.

3.1.1. Physical Process: The physical process is the pre-processing operation of direct combustion on biomass material. This physical processing operation is done on biomass to minimize the problem of diversity and heterogeneity. As regards to MGW like solid waste and pruning waste etc. their physical process improves densification and homogenization. It decreases the moisture content by 6 to 10% in wet bases but also increases the energy density retaining the calorific value of biomass. The physical process reduces logistics and transportation cost and also allows the use of automatic equipment for easy and quick movement of biomass. This physical process reduces the loss of heat, required for vaporizing and drying which improves the property of burning. The improved property of burning helps in complete combustion and reduces the emission of particulate matter or ash. The physical process makes the governing easy and meets the demand shortly. This process compensates the improvements in the final production. Hence physical process helps to ease the direct combustion [18].

3.1.2. Direct Combustion Process: Burning of biomass as firewood is a common, oldest and wide spread process as a cooking fuel. This direct combustion process can be carried out in great variety of equipment for several different purposes like stove for domestic cooking, furnace in food and service centers like restaurants and pizzerias, boiler for steam production in various industries for the purpose of cleaning, heating and generation of electricity through steam turbine. The direct combustion is the thermal process in which direct burning of biomass is performed under excess amount of oxygen or air and obtain very high temperature in combustion chamber.

$$CH_{1.44}O_{0.66} + 1.03O_2 = 0.72H_2O + CO_2 + Heat$$

Where, $CH_{1.44}O_{0.66}$is a chemical equation for combustible potion of biomass material.

The exhaust gases generated by combustion of biomass produces heat of very high temperature are used for the production of steam in the boiler and this steam is further heated by exhaust gases to produce super-heated steam. This steam is expanded in a steam turbine, due to firing of steam over steam turbine to generate the electrical energy by the alternator [19].

The biomass consumption rate for generation of electrical energy by thermal conversion technology depends upon the size of biomass plant. Larger the size of plant larger will be the consumption of biomass material and vice-versa. The biomass consumption rate varies from 1.22 to 1.57 kg per kWh. The Figure 3 below shows direct combustion process of biomass.

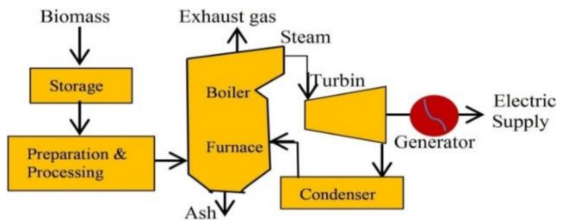

Figure 3 Direct Combustion Process of Biomass.

3.2. Thermo Chemical Conversion Technology

The Thermo Chemical Conversion Technologies (TCCT) is of following types:

3.2.1. Gasification: Gasification is one of the oldest thermo chemical conversion techniques of producing gas known as producer gas from carbonaceous based solid fuel material.

Gasification is a three step process as shown in figure 4 and is carried out by reacting solid biomass fuel material at very high temperature (> 700°C) [20-23, 25] with partial oxygen or air or steam produces synthesis gas consisting of H_2, CO, CO_2, CH_4 [24].

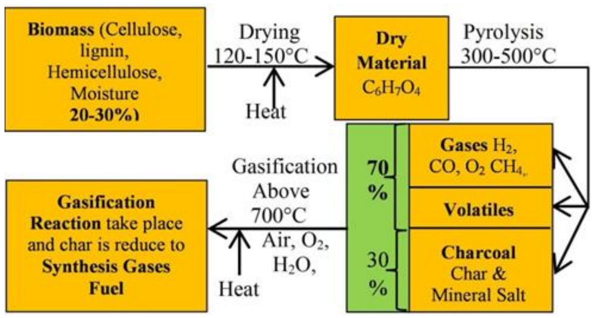

Figure 4 Gasification Flow Diagram.

The gasification is an incomplete or without combustion process due to sub-stoichiometric amount of oxygen used. Depending upon the amount of oxidation or air or steam supplied during gasification, the producer gas thus achieved, have different calorific values. During gasification if air is used as a gasification agent resulting nitrogen rich with lower calorific value of gas around 5 - 8 MJ/Nm^3 is produced. The air to be supplied is given by Air Equivalence Ratio (AER) [26].

$$AER = \frac{A_o(Kg / Kg_{biomass})}{A_e(Kg / Kg_{biomass})}$$

Where: *Ao*- represents mass ratio between air and biomass.

Ae- represents stoichiometric demand mass ratio of air for the total combustion of the same quantity of biomass.

Whereas during gasification if pure oxygen is used as a gasification agent resulting mixture of H_2 of CO rich with higher calorific value of gas around 10 - 12 MJ/Nm^3 is produced. During gasification if steam is used as a gasification agent resulting mixture of H_2 & CO_2 rich with highest calorific value of gas around 15 - 20 MJ/Nm^3 respectively [24, 27]. Calorific value of natural gas, then this gas is of around $44MJ/Nm^3$ [28]. Gasification process includes three main steps: First step is drying, in which water content is dried out from the biomass material, second step is pyrolysis process in which biomass material is broken up into volatile and char compound, in third step finally it is oxidized by the gasification agent like air oxygen, steam and char is reduce to synthesis gas [29]. Generally for biomass large number of small scale gasification system are found in operation and very few large scale gasification system are in operation say 2% of the total gasifies in operation [3]. If the feedstock input flow of biomass is continues than gasification technology is well suited for base load operation and if feedstock input flow of biomass is non-continues than gasification technology is well suited for peak load operation, by using a compressed gas strong facilities for this flexible energy generation system with compressed gas storing facility can be designed.

3.2.2. Pyrolysis: Pyrolysis is one of the oldest and most simple thermo chemical conversion techniques of charcoal from biomass fuel (firewood) into another fuel with better quality and more energy content than firewood. Four to ten tons of firewood with pyrolysis, produces a ton of charcoal or can say 30% of the original material [2, 19]. Pyrolysis is carried out by braking of solid/liquid biomass macromolecules into a smaller molecules of mixed solid, liquid, gaseous fuels at low temperature (<700°C) in the absence of air [20-25]. Therefore pyrolysis is an intermediate stage or incomplete process of gasification. As the step described in the gasification processor above, pyrolysis is the second step of the gasification in which after drying out the water content in the biomass, this biomass material is broken up into volatile and char compound. Further this volatile compound is partly cracked into gaseous side-products. Generally pyrolysis is produced in liquid phase called bio-oil can be used as fuel oil. As it is stated that temperature required for pyrolysis is less than 700°C which is significantly lower than that required in gasification and it is around 300°C to 500°C [34-37]. The literature related to the classification of three different pyrolysis process are given in [27, 33, 39-40]. Electrical generation technology is seems to be difficult in using pyrolysis liquid fuel say bio-oil [41]. Pyrolysis process is shown in figure 5.

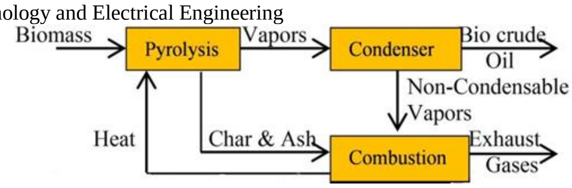

Figure 5 Pyrolysis Process of Biomass.

3.2.3. Liquefaction: Liquefaction is the earliest stage of development during the process of pyrolysis and gasification. Liquefaction is an intermediate fuel, produces with endothermic chemical reactions using pyrolysis and gasification process. During liquefaction the biomass macromolecules tries to cleave by applying high pressure of around 50 to 200 bar and at low temperature of about 200°C to 400°C [42-43]. Liquefaction product is seemingly liquid fuel with consistency similar to pyrolysis bio-oil. Process of pyrolysis bio-oil form biomass is shown in figure 6. However this oil is very rarely available and not used widely for small application [24, 27-43].

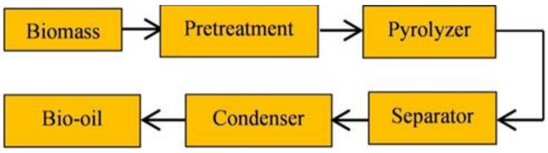

Figure 6 Liquefaction Process of Biomass.

3.2.4. Conclusion of Thermo Chemical Conversion Technology: From the above study of different TCCT it is concluded that gasification is best TCCT among the above three in terms of conversion level, time, simplicity, plant cost, micro scale application and electricity generation [44]. From the numerous reports of gasification process studies, 1kg/hr. throughput of biomass material is converted into gas of volume suitable to generate 1kW of electricity [21, 45-50].

3.3. Bio-Chemical Conversion Technology

A diluted feedstock with more than 50% moisture content or high water content biomass such as manures sludge and many more different watery waste in municipal waste can hardly been treated economically in TCCT. As the high energy input is required to heat the watery feedstock to vaporize the water content in the feedstock for the thermo chemical conversion. There is an alternative process to treat such water based material that is a bio-chemical treatment which is a more economical solution.

There are different processes from which the energy is extracted through Bio-Chemical Conversion Technology (BCCT) such two processes are; respiration process and fermentation process. The process that requires oxygen and sun light is known as respiration, while the process which does not required oxygen and sun light is known as fermentation. The respiration occurs in both large and small living organism and creature such as humans, animals and also in insects. In smaller living beings the process of respiration takes place in cytoplasm and moves into the

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mitochondria. In the respiration process living organism absorbs oxygen and is converted into carbon dioxide with the help of other organic substances. As the respiration occurs in large creatures the amount of ATP (energy) generated is relatively more of around 36 ATP. Whereas the fermentation occurs in microorganisms or in small living being which do not have the ability to intake oxygen like yeast and bacteria which take place in cytoplasm and cannot be carried to (out in) the mitochondria. In the fermentation process the sugar is converted into other form such as acids and alcohol. As the fermentation occurs in small creatures the amount of ATP (energy) generated is very less of around 2 ATP.

The respiration processes are of two types one is aerobic respiration process and another is anaerobic respiration process. Similarly fermentation process is also of two types one is aerobic fermentation process and another is anaerobic fermentation process. The aerobic fermentation is more precisely and scientifically termed as "Aerobic respiration". Hence the only process take place in fermentation is anaerobic process. Thus the three processes are considered i) Aerobic process, ii) Anaerobic Respiration, iii) Anaerobic Fermentation.

The bio-chemical process producing energy, serves two different processes one is aerobic process and another is anaerobic process. Aerobic process provides energy evenly as a constant source of energy, whereas anaerobic process provides quick energy in short notice when it is needed for a short period of time.

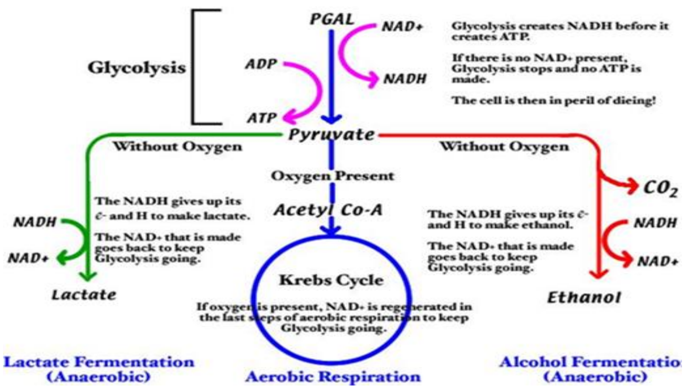

Figure 7 Aerobic and Anaerobic Processes.

The aerobic and anaerobic are the two digestive processes that have a same goal. These process use glucose as a starting molecule and undergoes the breakdown of glucose known as "glycolysis process", which is the first step of both the processes occurs independently in cytoplasm and in the absence of oxygen. During the first step of Glycolysis, the six carbon sugar is brokendown into two, which has three molecules of carbon called "pyruvate" and produces 2 net molecules of ATP (energy) for each broken molecules of glucose. Further the glucose goes through the different processes in aerobic and anaerobic processes and produce different amount of ATP (energy). After this first step of glycolysis, aerobic process and anaerobic process part ways. The aerobic process take place in the presence of oxygen and anaerobic process take place in the absence of oxygen. Figure 7 shows aerobic and anaerobic digestive processes.

3.3.1. Aerobic Process: Cellular respiration is a most common type of aerobic process takes place in the large bodies like plants, animals, humans, birds and mammals. The aerobic process is a set of biochemical reaction that occurs completely in the presence of oxygen and utilizing micro-organisms to degrade organic matter. An aerobic process is a first order kinetic reaction and follows the three process i) biomass degradation ii) nitrification and iii) de-nitrification [51]. In the biomass degradation process the food that contains carbohydrate molecules such as glucose is broken down by micro-organisms and in the process of breaking down of the food particles releases energy in the form of ATP. As said above in respiration an aerobic process takes place in cytoplasm and move onto mitochondria yielding inorganic and products like carbon dioxide and water.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2900kJ/mol$$
$$Glucose + Oxygen \rightarrow Carbondioxide + Water + Energy$$

Aerobic process under goes three steps first step is glycolysis which is common to both aerobic process and anaerobic process is explain above, second step is a Krebs cycle and the third step is electron transport chain.

The second step is Krebs cycle occurs inside the mitochondria in which the output of glycolysis (first step) is pyruvate which is transferred into the mitochondria matrix. Pyruvate undergoes oxidative decarboxylation and forms acetyl coenzyme A (acetyl-CoA) with the elimination of carbon dioxide. This acetyl-CoA then invades into the citric acid cycle. During this citric acid cycle, single glucose molecule is entirely oxidized and produces six carbon dioxide molecules, 2 GTP, 6NADH, and $2FADH_2$ molecules.

Third step is Electron Transport chain which occurs in the inner membrane of mitochondria. In the inner membrane of mitochondria oxidative phosphorylation takes place in which the output of Krebs cycle that is NADH and $FADH_2$ are combined with oxygen which is the final electron acceptor of electron transport chain to generate ATP. Thus transfer of electrons through a series of carrier that has taken place in this electron transport chain. Therefore the aerobic process is the most efficient process among various process of energy that produces energy of 34-36 ATP or 2900KJ / mol.

Aerobic process is generally used for treating different types of wastewater known as aerobic granulation technology. The wastewater such as toxic wastewater, bebeerine waste water, and high strength wastewater containing phenol, xenobioties and endocrine disrupters are treated [51-53]. The granular sludge is cultivated by degrading waste water using different reactor such as Activated Sludge Reactor (ASR), Sequencing Batch Reactor (SBR) and Membrane Bioreactor (MBR) etc. During granulation suspended

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solid (SS), volatile suspended solid (VSS), sludge volume, chemical oxygen demand (COD), berberine etc. are removed efficiently and mature granules are obtained. Let us discussed different reactors and methods used for obtaining mature granules by treating different wastewater. Aerobic granule is the self-aggregated granular microbial, cultivated in aerobic condition. Compared with common activated sludge system, the granules are characterized with high microbial density, excellent settling ability, little surplus sludge and simple separation process for effluent.

Zang L., et al. had used domestic waste water in SBR to cultivate aerobic granular sludge. The hydraulic shear stress and hydraulic retention time where used to carry out the control over the aerobic granular sludge cultivation. The aerobic granular sludge was established when mature granular sludge was inoculated into MBR to develop aerobic granular sludge membrane bioreactor (AGSMBR). Here COD, NH3-N, and TN are removed from the wastewater. The difference in removal efficiency of COD, NH3-N in MBR and AGSMBR is less whereas removal efficiency of TN in AGSMBR is much more than in MBR [55]. Wang Xin-gang et al. had studied the aerobic granulation technology using flocculent activated sludge called seed sludge as an aerobic granular sludge was cultivated successfully in SBR. In this process effluent of COD was reduced [56]. Sheng G., et al. had used both synthetic domestic wastewater and ordinary flocculent activated sludge as seed sludge from Third Sewage Treatment Plant in Xi'an in SBR to cultivating aerobic granular sludge. The controlling over aerobic granule sludge was carried out by high hydraulic shear stress. The COD, TN and TP are removed in high rate. The percentage removal of COD, TN and TP is much more than that by the Third Sewage Treatment Plant in Xi'an [57]. Feng-hua Liu et al. used Anaerobic Baffled Reactor (ABR) to cultivate aerobic granules for berberine wastewater treatment. Berberine is an antibiotic and is more toxic than phenol to aquatic species. It also provide information for coupling of aerobic granular technology using SBR for cultivating aerobic granular sludge as it operates at room temperature of 20°C to 30°C and ABR for treating berberine wastewater to remove organic and berberine. It is further proceeding with the production of aerobic granules [58].

3.3.2. Anaerobic Process: Cellular respiration takes place in microorganism like bacteria, yeast and parasitic worms. The anaerobic process is a set of bio-chemical reactions that occurs in the absence of oxygen. In this process the food that contains carbohydrate such as glucose is broken down in simple organic compounds and the process of breaking down the food particles releases energy in the form of ATP. As said above in the anaerobic respiration, an anaerobic process take place in cytoplasm yielding organic compounds like Lactic acid, ethanol, carbon dioxide, methane and hydrogen sulfide. The different types of MGW residual waste which were used to produce biogas for the generation of electrical energy by adopting through anaerobic processes are discussed as under-

Urban pruning waste is a primary residue and is used for generation of electricity in Brazil, North America and European countries using anaerobic digestion process. An anaerobic digestion process yields 125Nm3 of biogas, 500kg of compost and 300kg of liquid fertilizer from one tone of urban pruning waste when fed to an anaerobic digester. The motor generator system is used for the conversion of biogas into electric power generates 0.232 W/Nm3 of biogas fed [19].

Secondary residue also includes livestock waste and MSW. The livestock waste and MSW are converted into biogas using anaerobic digestion process. An alga is produced from livestock waste and other municipal waste can be used to generate bio-oil [59]. This conversion makes the proper utilization of livestock waste and MGW and reduces noxious gases, harmful pathogens, odor and unhealthy environment. The byproduct of biogas is compost and vermicompost are very useful to increase crop yield and sustainability of soil. Globally 40% of the methane production is through livestock and agriculture byproduct besides this 18% of the methane production by MGW [60]. It is the ability of livestock to produce energy, the biogas from livestock is the most popular product in many of countries of the world. From one ton of manure includes 20% of solid content produces 20-25m^3 biogas, this biogas can produce 100-125 kWh of total energy and the same can be utilized to generate 55-75 kWh of heat energy and 35-40 kWh of electrical energy [61]. This biogas is produced by either composting or anaerobic process as these are the famous technologies [62].

The animal waste, human waste and food waste are the tertiary residues are also the good feedstock for an anaerobic digester. The animal waste such as dung and urine can produces biogas through anaerobic process, whereas 12-15 kg of animal waste produce 1m^3 of biogas whose calorific value is 4700-6000 kcal/m^3 which generates 6 kWh of electrical energy as 860kcal will produces 1kWh of electrical energy [63]. If the food waste is used for the production of biogas through anaerobic process, the food waste which includes food preparation waste say kitchen waste, vegetable and vegetable market waste and uneaten and leftover food from restaurant, food market, commercial sources (hotel, food providing business and hostel), residential and institutional sources can be degraded by using anaerobic digesters to yield methane. Here the collected food waste from commercial restaurants is characterized for assessing their potential to use as a feedstock for biochemical anaerobic digestion process. It analysis the consistency, overall variability of the food waste over a time and determine methane yield from food waste during anaerobic digestion at 50°C with two different initial loading. This study also indicates that food waste

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can be converted into biogas energy and is highly suitable substrate for anaerobic digester [64]. Cho and Park, Heo and Park had also yield methane from different food wasters, different digestion time at different temperature [65-66]. This concludes that the performance of anaerobic digestion process depends upon many factors like its design, feedstock characteristics and operating conditions [67-68].

For the large moisture content, volatile solid and total solid in a leftover food waste, the bio-chemical anaerobic digestion process are more suitable compared to TCT and TCCT such as direct combustion and gasification. The anaerobic process is also widely applied for treatment of organic wastes that can be easily biodegraded in anaerobic digestion [69-71]. If a wastewater contains Terra-Methyl Ammonium Hydroxide (TMAH) and if it is treated by anaerobic biodegradation technology the methanogen is isolated which is energy potential. Methanogen grows on TAMH as a sole source of energy. The methanogen yield was approximately 2.5g/molCH_4 with a 30mM of TMAH as a sole source of energy and carbon [72]. This methanogen can use Three Tetra- Methyl Ammonium (TMA) as a substrate and metabolizes TMA to produce 3CH_4, 1CO_2 and 1NH_3 [73]. For treating a wastewater anaerobic biodegradation technology is the most economical method as it requires low investment for land and construction cost, low operation cost and it also recover potential energy as compared to an aerobic biodegradation technology [74].

Anaerobic processes are identified by two categories 1) Anaerobic Respiration, 2) Anaerobic Fermentation. One category is anaerobic respiration is similar to aerobic respiration and second categories is anaerobic fermentation is similar to aerobic respiration and anaerobic respiration. Figure 8 shows the anaerobic processes.

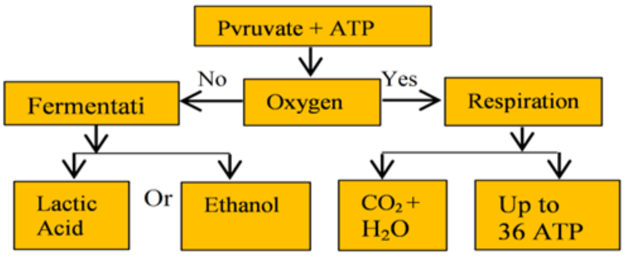

Figure 8 Anaerobic Processes.

3.3.2.1. Anaerobic Respiration: As in aerobic respiration the first step of glycolysis of generating two pyruvate molecules, 2ATP, 2NADH molecules from brokendown of food that contain carbohydrate molecules such as glucose. The pyruvate molecules undergoes oxidative decarboxylation and from acetyl-CoA. Thus acetyl-CoA is than invades into citric acid cycle and continues with the electron transport chain. To continue working of electron transport chain there must be a need of final electron acceptor, up to final electron acceptor the process is same as an aerobic, but in anaerobic respiration the final electron acceptor may be carbon dioxide, nitration, and sulfate-ion. Depending up on the organisms which includes prokaryotes bacteria's and archara present at the end reaction of electron transport chain can use different final electron acceptors. If archaea use carbon dioxide (CO_2) as a final electron acceptor, it produces methane as a byproduct and if it use sulfates (SO_4) as a final electron acceptor it produces hydrogen sulfide (H_2S) as a byproduct.

3.3.2.2 Anaerobic Fermentation: The first step of aerobic respiration and anaerobic respiration is glycolysis, in which the breakdown of the food that contain carbohydrate molecules such as glucose by microorganism into ethanol or lactic acid. Due to incomplete oxidation of pyruvate molecules that generates from glycolysis it does not continue with oxidation and citric acid cycle and hence in fermentation electron transport chain does not run. From the above two steps anaerobic fermentation the glycolysis and partial oxidation of pyruvate, the pyruvate is not the final product and depending on the type of fermentation the final product is a different molecule. There are two types of mechanisms of anaerobic fermentation based on pathway of pyruvate oxidation, one is Ethanol/Alcoholic fermentation and other is Lactic acid fermentation are explained below.

Yahong Liang, et al. used wheat straw and fallen leaves were used as a raw material for anaerobic fermentation. This raw material was collected from Xi'an City and Xi'an Uni. of Archt. and Tech. campus respectively, the inoculums sludge from Shaanxi return sludge treatment plant. An experimental test of solid-state anaerobic digestion are carried out on wheat straw, leave and mixture of both in 2:1 ratio at different temperature ranges from 313° K to 328° K (39.85° C to 54.85° C). This raw material are pretreated by adding BM cellulous as a bacterial agent with a 1/200 ratio, once 4 to 7 days of pretreatment stage is over this pretreated raw material added with 30% to 40% inoculated sludge and put for anaerobic digestion. The pretreatment time, anaerobic digestion and gas production of a raw material is different for different feed temperature. If the start-up feed temperature is high, the thermophilic's and anaerobic bacterium made rapid degradation of raw material and produces a bio-gas. The produced gas was collected according to the law of drainage set gas. If the feed temperature is between 278°K to 292° K (4.85° C to 18.85° C) the gas production may take place but some time it may even stop. If the feed temperature is 326°K, the pretreatment time is least (four days) and bio-gas yield is large and for longer time. Thus it is seen that with the appropriate feed temperature on solid-state anaerobic digestion will effectively increase the bio-gas production [75].

I. Ethanol Fermentation: Ethanol fermentation is an alcoholic fermentation mainly occurs in presence of yeast (Zymase). In the ethanol fermentation with the help of zymase carbon dioxide is removed resulting in decarboxylation of pyruvate into acetaldehyde. The hydrogen atom of NADH generated during glycolysis is used to convert acetaldehyde into ethanol. Thus in balance chemical reaction for ethanol fermentation is one molecule of glucose is converted into two molecules of ethanol and two molecules of ATP & NAD, the process is a follow.

$$C_6H_{12}O_6 \xrightarrow{Yeast} 2CH_3COCOOH \rightarrow 2CH_3COH + 2CO_2 \rightarrow 2C_2H_5OH + 118kJ/mol$$

$$Glucose \xrightarrow{Yeast} 2Pyruvate \rightarrow 2Acetaldehyde + 2Carbondioxide \rightarrow 2Ethanol + Energy$$

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 118kJ/mol$$
$$Glucose \rightarrow 2Ethanol + 2Carbondioxide + Energy$$

1) $C_6H_{12}O_6 + 2ADP + 2Pi + 2NAD \xrightarrow{Glycolysis} 2CH_3COCOOH + 2ATP + 2NADH + 2H$
2) $2CH_3COCOOH \rightarrow 2CH_3COH + 2CO_2$
3) $2CH_3COH + 2NADH + 2H \rightarrow 2C_2H_5OH + 2NAD$

II. Lactic Acid Fermentation: Lactic acid fermentation is mainly occurs in insufficient amount of oxygen supply and it may allow aerobic respiration to continue. Lactic acid fermentation is carried out in the presence of bacteria (Yogurt). In the lactic acid fermentation, the lactate dehydrogenase convert pyruvate to lactate by adding a proton that is hydrogen atom (H^+) to the pyruvate and in this process the NADH generated from glycolysis is converted back to NAD^+.

Thus in the balance reaction one molecule of glucose is converted into two molecule of lactate in homolactic lactic acid fermentation where as in heterolactic lactic acid fermentation one molecule of glucose is converted into one molecule of lactate, one molecule of ethanol and one molecule of carbon dioxide.

$$C_6H_{12}O_6 \rightarrow 2CH_3COCOOH \rightarrow 2C_3H_6O_3 + 120kJ/mol$$
$$Glucose \xrightarrow{Bacteria} 2Pyruvate \rightarrow 2Lactate + Energy$$

Homolactic Lactic acid fermentation:

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + 120kJ/mol$$
$$Glucose \rightarrow Lactate + Energy$$

Heterolactate Lactic acid fermentation:

$$C_6H_{12}O_6 \rightarrow C_3H_6O_3 + C_2H_5OH + CO_2 + 120kJ/mol$$
$$Glucose \rightarrow Lactate + Ethanol + CO_2 + Energy$$

$$C_6H_{12}O_6 + 2ADP + 2Pi + 2NAD \xrightarrow{Glycolysis} 2CH_3COCOOH + 2ATP + 2NADH + 2H2CH_3COCOOH + 2NADH + 2H \rightarrow 2C_3H_6O_3 + 120kJ/mol$$

After distilling alcoholic liquor the by-product of distillation is distiller's waste. This distiller's wastes are treated as a biomass wastes which are available in large quantity where production alcoholic liquor is takes place. This distiller's waste contains plentiful vitamins, crude protein, nutritious, amino acid, and variety of inactive elements. Owing to this distiller's wastes properties, lot of research work is carried out as resource utilization of distiller's waste. SHEN Jin-Peng, et al. used anaerobic fermentation of distiller's wastes for preparation of bacterial cellulose [76]. Drew J. Cookman, et al. extracted protein from distiller's wastes by fermentation [77]. From the fermentation Liu J.G., et al. had showed effect of pretreatment methods on L for Lactic acid production [78]. Whereas Li-Hong, et al. analyzed on biogas production and anaerobic digestion process of a distiller's waste through lactic acid fermentation. The distiller's waste under goes lactic acid fermentation, the percolated liquid from the solid is stored in refrigerator. Thus from this fermented residue the methane is produced in an anaerobic digestion. This anaerobic digestion process is conducted at 37℃ and process is carried out in 34 days [79]. The methane production rate of the fermentation residue could be 146.32mL/gTS, about equally with that of wheat straw and sunflower plate [80-81].

3.3.3. Conclusion of Bio-Chemical Conversion Technology: Thus from the above bio-chemical conversion processes which have been studied are aerobic process, anaerobic process and fermentation process. The output of aerobic process is a carbon dioxide gas which is a very versatile material used in many commercial processes, but it does not supports combustion and also it is not a flammable one. Thus carbon dioxide gas is not used for generation of electrical energy though heat engines. From the fermentation process we get ethanol and Lactate (lactic acid) as a final product. Though the ethanol is easy to handle and store than other gases, but the fermentation process is more complex and need intensive pre-treatment and necessary temperature to the feedstock. Adding to this fermentation process is less suitable for micro-scale energy generation. From the anaerobic process methane is produced; production of methane through anaerobic process is the simple process. The methane provides great environmental benefits, giving high heat and electrical energy in comparison with other fuels and producing significantly less carbon dioxide and other pollutants. The energy produced by methane is 15.4 kWh/Kg which is twice that of the energy by ethanol. Due to all these properties methane is considered as a clean and ideal fuel. The great advantage of yielding methane is that there is a broad range of methane based engines for producing heat and electrical energy are available [82]. Thus it is concluded that anaerobic process is more efficient and suitable for energy generation than aerobic process and fermentation process. Table 1 below gives the brief summary of bio-energy conversion technology, processes, types and its description.

Table 1.:- Bio-Energy Conversion Technology with types, processes and their descriptions.

Process	Conversion Technology	Types of Process	Description	References
Combustion	Thermal Conv. Tech.	Physical Process	It is pre-prosing operation of direct combustion. It is for densification and homogenization of biomass solid material.	[18].
		Direct Process	In this direct burning of solid biomass under excess amount of oxygen/air and obtain very high temperature.	[19].
Gasification	Thermo Chemical Conv. Tech.		It is an incomplete combustion.it is carried out at very high temperature above 700°C with partial oxygen/air/steam produces synthesis gases (H_2, CO, CO_2, CH_4) with different calorific values.	[20-25]
Pyrolysis	Thermo Chemical Conv. Tech.		It is an intermediate stage of gasification. It is carried out by braking of solid / liquid biomass macromolecules into a smaller molecule of mixed solid, liquid, gaseous fuels at low temperature. It is carried out in the absence of air. it take place at a temperature less than 7000C which is significantly lower than that required in gasification and is around 3000C to 5000C.	[20-25, 34-37]
Liquefaction	Thermo Chemical Conv. Tech.		It is the earliest stage of development during the process of pyrolysis and gasification. It produces with endothermic chemical reactions using pyrolysis and gasification process. During liquefaction the biomass macromolecules tries to cleave by applying high pressure of around 50 to 200 bar and at low temperature of about 2000C to 4000C.	[32,42-43]
Aerobic Process	Bio Chemical Conv. Tech.		In this biomass contains carbohydrate molecules such as glucose is degraded by microorganisms in the presence of oxygen and this broken down of the food particles releases energy in the form of ATP. An aerobic process is a first order kinetic reaction and follows the three process 1] biomass destruction / degradation 2] Nitrification 3] de-nitrification. As said above in respiration an aerobic process takes place in cytoplasm and move onto mitochondria yielding inorganic and products like carbon dioxide, water and 2900KJ/mole of energy. Aerobic process under goes three steps first step is glycolysis which is common to both aerobic process and anaerobic process is explain above, second step is a Krebs cycle and the third step is electron transport chain. Aerobic process is generally used for treating different types of wastewater known as aerobic granulation technology.	[51-54, 58]
Anaerobic Process	Bio Chemical Conv. Tech.	Anaerobic Respiration	In an anaerobic respiration up to final electron acceptor the process is same as an aerobic process. To continue working in electron transport chain there must be a need of final electron acceptor, but in anaerobic respiration the final electron acceptor may be carbon dioxide, nitrate-ion, and sulfate-ion. Depending up on the organisms which includes prokaryotes bacteria's and archara present at the end reaction of electron transport chain can use different final electron acceptors. If archaea use CO_2, it produces methane as a byproduct, if archaea use SO_4 it produces H_2S as a byproduct.	[59, 61-63, 66].
		Anaerobic Fermentation	As in the first step of an aerobic respiration and anaerobic respiration is glycolysis, in which the breakdown of the food that contain carbohydrate molecules such as glucose by microorganism into ethanol or lactic acid. In fermentation electron transport chain does not run. From the above two steps anaerobic fermentation the glycolysis and partial oxidation of pyruvate, the pyruvate is not the final product and depending on the type of fermentation the final product is a different molecule. There are two types of mechanisms of anaerobic fermentation based on pathway of pyruvate oxidation, one is Ethanol/Alcohol fermentation and other is Lactic acid fermentation.	[75].
Anaerobic Fermentation	Bio Chemical Conv. Tech.	Ethanol Fermentation	Ethanol fermentation mainly occurs in presence of yeast (Zymase). In the ethanol fermentation with the help of zymase carbon dioxide is removed resulting in decarboxylation of pyruvate into acetaldehyde. The hydrogen atom of NADH generated during glycolysis is used to convert acetaldehyde into ethanol.	[76-78].
		Lactic acid Fermentation	Lactic acid fermentation is carried out in the presence of bacteria (Yogurt), the lactate dehydrogenase convert pyruvate to lactate by adding a proton that is hydrogen atom (H^+) to the pyruvateand in this process the NADH generated from glycolysis is converted back to NAD^+	[79-81].

4. CONCLUSION

Thus from the above study there are three conversion technologies which are used depending upon the biomass material available in that place. Thermal Conversion Technology is used where dried forestry and pruning waste is available. This type of conversion technology is used for the production of bio-energy in megawatts, as in non-conventional thermal power plant and in CHP. Thermo Chemical Conversion Technology is used in a reactor where solid biomass fuel is treated at very high temperature partial amount of air. This conversion technology is suitable for production of bio-energy in kilowatts. It is also more initial processing and maintenance. In the Thermo Chemical Conversion Technology gasification is the best method of biogas generation. Bio Chemical Conversion Technology is used for many more type of waste which contain large amount of moisture, it also suitable for MSW and MGW. In the Bio Chemical Conversion Technology anaerobic process is the best method of biogas generation. From all the three conversion technology study, for large production of bio-energy direct combustion in Thermal Conversion Technology is the best suited and for small generation of bio-energy, anaerobic process in Bio Chemical Conversion Technology is the best suited as it is most economical, easy to handle and has less maintenance.

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