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Review Article

Impact of Renewable Bioenergy Potential for Sustainable Development – A Review

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Abstract

The burning of huge amounts of non-renewable fossil fuel has unfavorable significance on the climate, environment and living beings. The application of renewable bioenergy resources is considered an environment friendly and sustainable substitute for fossil fuels. Biomass as a renewable resource has gained incredible attention due to its potential to produce bioenergy in the form of solid, liquid and gaseous fuels for transportation, heat and electricity generation and industries. This review mainly discusses the importance of biomass resources, scope and advances technology in converting biomass to bioenergy, challenges opportunities, energy policies within global. Presently, many novel physical, chemical, and biological ways are used to produce renewable bioenergy. Its shows a bright future in energy production globally if effectively used.

Keywords: Biomass; Bioenergy; Biofuel; Renewable Bioenergy

Introduction

Biomass has been a major energy source for mankind and 10%-14% of the global energy supply is contributed by biomass. Although the bioenergy potential is underrated due to lack of information, the residues from the production of the grain are husk and coffee pulp, which can be used as biomass, building coffee waste from the food industry and agribusiness. Although there is still scarce literature about strengths, scarce literature and weaknesses about the process should be pointed out. Both sectors produce huge quantities of coffee waste, both solid and liquid since the second largest product traded in the world is coffee after oil. Coffee allows many ways to exploit its disposal due to continuous worldwide energy demand and sustainable production. The development of new technologies, on the other hand, describes the proposition and framework section. There has been a considerable improvement in the process of generation, where combusted husk and coffee pulp are used. Such combustion is a compound process that involves heat transfer and coupling mass with fluid flow and chemical reaction which should be done simultaneously. Therefore, the husk and pulp of coffee would be a biomass source that can be used as an additive to help combustion using large volumes of waste heat in a boiler. But it is required to undergo research in this area to find a satisfactory solution for using both forms of waste since the calorific potential of this organic product is high and it can be used for energy production by pyrolysis.

It is notable that the literature on this type of renewable energy is very sparse. Pyrolysis results in the formation of three-phase products by means of thermally decomposing the feedstocks at a temperature range of 300°C-900°C with the presence of limited O_2. The value-added products generated from waste play an important role in using the waste in a different manner. When the waste is generated, it is sent to landfills, and the production of methane is 34 times more likely to produce carbon dioxide and contribute to global warming [1].

The production of high energy fuel that includes biogas, bioethanol, and biodiesel is for the reduction of the carbon footprint [2]. The combustion process is commonly used to form the energy from the waste produced. This process includes the waste reacting with an excess amount of oxygen to generate energy. Pyrolysis is another method of producing energy from waste. The thermal degradation of the waste at a very high temperature without oxygen [3]. Anaerobic digestion is the production of biogas and biofertilizers by breaking the organic wastes. The generation of heat and electricity is possible from Biogas, which has a similar chemical composition as natural gas [4]. Electricity generation is 17.3 times more logical than coal and 3.2 times more than oil [5].

Biomass is considered the fourth largest energy-producing source in the world followed by coal, oil, and natural gas, and also considered one of the most efficient energy sources [6]. Biofuel is a widely used and renewable resource that could also be developed in the future. Another important point is, it has environmentally friendly properties like reduction of greenhouse gas, NOx, and SOx emitted by fossil fuels is deducted.

There are types of liquid biofuels based on the feedstock used in manufacturing [7].

First generation Biofuel

It is majorly acquired from animal feed and food products [8]. Different varieties of techniques are used such as fermentation, distillation, and transesterification, which are referred to as 'conventional biofuels' [8]. The major center is the production of fuel and the non-fuel matter generated by this process is discarded as waste [9].

Second generation Biofuel

This type of fuel is generated by non-fuel stocks, for example, energy producing crops and lignocellulosic plants, forest leftovers, and agricultural wastes [8]. Comparatively, this second-generation method is an improved method, which helps in increasing the rate of both fuel and non-fuel products generated. Overall, it produces cost-effective, less waste-generated fuel. For further improved quality of fuel, researchers use techniques like membrane filtration and integration, in which various microorganisms are used to generate amino acids, organic acids, and biofuel [9].

Third-generation biofuel

They are obtained from microalgae through hydrotreatment or transesterification of the algal oil [8]. This method has increased yield of the biofuel, then the first generation biofuel [10]. Research is being done every day to get a better product of second and third generation biofuel [8]. They do not make a change in the food chain either, and they are also very feasible. The vital resources by which they are obtained are microalgae, animal oils, fish oil, animal fat, etc. The added advantage is, it helps in decreasing the rate of water pollution by using the algae grown around the water body [11].

Fourth generation biofuel

This kind of biofuel is generated by genetically modified (GM) algae, photobiological solar fuels and electro-fuels [11]. They are helpful in increasing the quality of fuel, improving the photosynthetic efficiency, and increase light penetration [12]. Thy are economically cheaper compared to other generation fuels and inexhaustible. The tools that are using for genome editing is zinc finger nuclease (ZFN), transcription like effector nuclease (TALEN), and other bioinformatics tools [12].

Methods of biomass conversion

There are two main processes of conversion, Thermo-chemical, and Bio-chemical conversion. Biomass can be converted into three main products, Heat, electricity, and power.

Thermochemical process

This process is the conversion of biomass under high pressure and fast pyrolysis (World Bioenergy Association, 2020]. The bio-oil is majorly formed by this process.

Pyrolysis

Pyrolysis is the process of conversion of biomass into biofuel under heat and anaerobic conditions (without oxygen), by breaking the chain of longer molecules into shorter ones [15]. Usually, biomass and wastes are used in the production of liquid fuels and syngas by changing conditions [16]. It is advantageous because it can be stored and transported easily. The disadvantage is, it requires a lot of heat as input for a good amount of syngas as output [15].

Carbonization

Carbonisation is a similar slow process of pyrolysis, which is used to produce charcoal [15]. The three basic steps that are involved in this process are

- Controlled combustion and internal heating of raw materials
- External heating of the fuels
- Circulating gas for production of chemicals.

Combustion

It is the process of burning of the mass in the presence of oxygen, to transform chemical energy to mechanical, or electrical energy. Various apparatus are used for the process of combustion. Stoves, boilers, steam turbines, and turbo-generators are a few examples [17]. The limitation of this process is it emits a lot of hazardous gases such as carbon dioxide and nitric acid [18].

Gasification

This process is the production of high-energy fuels like syngas and fuel gas (World Bioenergy Association, 2020). There are many products that can be further formed such as methanol, and hydrogen which are used on daily basis [17].

Liquefaction

It is the conversion of the biomass to liquid hydrocarbons which are stable, unclear low temperatures and high pressure of hydrogen [17]. This provides us bio-oils, and a mixture of volatile organic acids, aldehydes, ethers, and hydrocarbons. Alcohol and other non-volatile compounds [16]. The catalyst can also be used to produce more dense products [15].

Fermentation

It is a biochemical process for the production of ethanol from the starch crops and sugar, such as sugarcane and wheat. It is broken down to saccharides and then converted using enzymes, and fermented using yeast for the production of ethanol. Later part, it is purified. The solid waste that is left out is not thrown away, they are used to feed cattle or use as fuel for the boilers [15].

Anaerobic digestion

AD process is the digestion of the feedstock in the absence of oxygen and release heat, methane, hydrogen sulphide and carbon dioxide. This process is taken care in the large tanks and in the underground to maintain the temperature and the large area is required. After several days Biogas is formed.

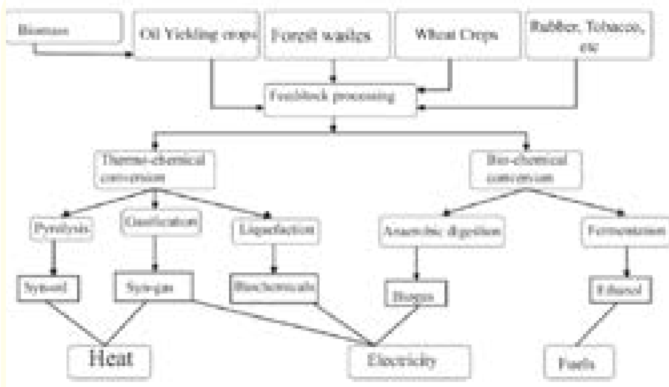

Figure 1: Feedstock processing and products.

Electricity generation based on biomass residue

Agricultural crops and industrial crops are examined. The global demand for fossil fuels has increased in the year 2021. Alone, the demand for coal has increased to 60% and the emissions will also increase by 5% (Global energy review 2021]. The restricted amount of fuel produced by fossil fuels diverted the government to move toward another source of energy [19]. The consumption of energy in the world will increase by 49% from 2007 to 2035 [20]. 94.5% of the electricity that was generated in Malaysia was by fossil fuels, such as petroleum, natural gas, and coal [21]. Even though Malaysia has multiple resources such as solar, wind, and water, they still depend on fossil fuels [22]. There is always a gloomy impact on the environment by using fossil fuels [23]. The greenhouse gases produced after burning of the fossil fuels are CH_4, N_2O and O_3 contribute to the global warming effect and ozone depletion [24].

The temperature in Malaysia has increased by 0.5-degree celsius to 1.5degree celsius, and predictions are to face drought and flood in the coming years (Press Malaysia, 2011). The energy consumption in Malaysia will be tripled by 2030 from 2004, hence the environment must be protected in Malaysia, by getting a long-term plan [25]. As a result, biomass residue can be used to produce biofuel with less emission of CO_2 [26]. Resources that can be produced for the production of biofuel are crops, trees, agricultural wastes, forest wastes, and plantation residue [27]. Plantation residue includes rubber, palm oil, wood, timber, etc. These produce high potential biomass residue which can be further used for the generation of electricity.

Palm oil, which is produced the second most in the world after Indonesia, similarly produces the waste produced by palm (Malaysia Oil Palm Statistics, 2009). The wastes that are produced by palm are 60% and utilized to generate steam and electricity [28]. Study shows that just the shell and fiber produced by palm is more than the energy required in the mills of palm oil [21]. The fibrous waste produced from Sugarcane bagasse is crushed and extracted from the sugarcane, has the potential of generating electricity equal to 1.6 barrels of fuel [29]. The residues from agricultural crops are divided into two groups, agricultural residues, and crop residues [30]. High potential energy can be generated by the residues. There are so many agricultural residues produced such as rice husk, coffee pulp, coconut, pineapple, and tea. Rice husk can produce potential energy after wood and palm oil. The two rice mills in the northern part of the country consume 86,400 tonnes of rice husk per annum and can produce power of around 700 kW to 1500 kW (Official Portal of Agriculture Department. 2011).

Pineapple waste is produced in the country, which is a potential waste. In the country, the Philippines has 220 tonnes of pulp per day which has the potential to generate 4MW of power [31]. Electricity can be generated using three types of technologies, they are combustion, pyrolysis, and gasification [32]. Combustion is most widely used, contributing to over 97% of the production of bio-energy [33]. It is used to convert biomass energy to heat energy and then into electrical energy at a high temperature of 800-1000 degree celsius [34]. Gasification is another process, a thermal breakdown of the biomass in the presence of oxygen. The gases produced by the process are very efficient for power generation (IEA. Task 33, 2012). The generation of electricity cost is dependent on the investment cost. The capital cost, operational cost, maintenance, power capacity, heat, and fuel cost are included [35]. To get away from power generation costs, developers should look for the long-term solution, which reduces the use of fossil fuels and takes up biofuel [36]. Biomass gasification proposes an economical way of hydrogen production [37].

Topic	First generation fuel	Second generation fuel	Third generation fuel	Fourth generation fuel	Reference
Major benefits	Simple conversion process	Do not affect the food chain	Raw materials can be obtained from cheap sources	Increased carbon dioxide absorbing and lipid content	[12,14]
Manufacturing cost	Economically feasible	Complicated conversion technology, less economical	Oil extraction process are expensive	Initial investment, and pilot setup is expensive	[12]
Chemical fertilizers and pesticides	Principally used	Not consumed	Not consumed	Not consumed	[12,14]
Nutrient requirement	Depends on fertilizers and pesticides	Not Dependant on any fertilizer and pesticide	Depends on carbon and nitrogen. Nutrients can be recycled, solar energy can be used	Depends on carbon and nitrogen. Nutrients can be recycled, solar energy can be used	[12,14]
Water footprint	Requires portable water for generation of biofuel	Requires portable water for generation of biofuel	Can use waste, saline, non potable water	Can use waste, saline, non potable water	[12,14]
Feedstock Land footprint	Easily available crops, edible oil, and starch	Non-food crops	Non-food crops Non-arable land	Non-food crops Non-arable land	[12,14]
Harvesting	Done by machine and handpicking	Done by machine and handpicking	Microalgae harvesting is complex and not economical	Microalgae harvesting is complex and not economical	[12,14]
Environmental risk	Using fertilizers and pesticides is harmful	Major risk is deforestation	Major risk is marine eutrophication	GMO release can be a threat	[12,14]

Table 1: Comparison between the Generation of fuels.

	Geothermal	Tide, ocean etc	Solar Thermal	Hydro	Solar PV	Wind	Biomass	Total
2016	3.37	0.004	1.41	14.6	1.18	3.45	56.5	80.5
2015	3.10	0.004	1.37	14.0	0.89	3.02	55.4	77.8
2010	2.62	0.002	0.66	12.4	0.12	1.23	50.8	67.8
2005	2.25	0.002	0.30	10.6	0.01	0.37	45.9	59.4
2000	2.19	0.002	0.22	9.43	0.00	0.11	42.8	54.8

Table 2: Total primary energy supply of renewables globally (Source: IEA Key World Energy Statistics).

Components of biomass	Calorific value (MJ/kg)	Amount of electricity generated (GW/h)	Reference
Coconut residue			
Frond	19.6	0.84	[38]
Shell	20.15	0.84	[39]
Husk	19.6	0.18	[38]
Bunches	19.6	0.02	[38]
Top and Trashier	17.45	0.21	[40]
Palm oil residue			
Shell	23.51	5792.13	[41]
Fibre	22.07	1578.19	[41]
EFB	21.52	46346.15	[41]
Paddy residue			
Rice straw	14.71	1.59	[42]
Rice husk	15.8	0.51	[43]
Sugarcane Bagasse	18.11	0.21	[40]

Table 3: Biomass collected in year 2009 and the potential electricity generated.

Thermal decomposition of the feedstock requires the temperature range of 300 to 900-degree celsius, with the presence of oxygen. This process of pyrolysis results in three phases of products (Review of fast pyrolysis, 2010). Anaerobic digestion produces the gaseous products, converting methanol to ethanol [44]. When the biomass is burnt down, it is converted to solid, liquid, and gaseous fuels, in the presence of oxygen and releases carbon dioxide to the atmosphere [45]. There are characteristics of each fuel which has to be checked: (i) Biomass thermal utilization cost (ii) weather availability (iii) complexity of the fuel burning (iv) barriers when the fuel has to be stored (v) combustion emissions (vi) the technology of the boiler required in making of the fuel. Although after using pyrolysis, the product can be refined to make the coffee biofuel with 5.16 mm^2/s kinematic viscosity, 4h of oxidation stability, and cetane number of 53 [46].

Fuel Type	Fixed carbon	Ash content	Volatile matter	MJ/Kg
Coffee parchment husk	20.70	2.80	76.80	18.2

Table 4: Calorific Coffee Waste [46].

Biomass can be obtained in two ways. One, it is obtained naturally. Second, the byproducts of human activities have an efficiency of 70% [18]. The emissions produced by biomass to bioenergy have to be reduced, which is very high [47]. Biomass has a lower calorific value due to more moisture content in the biomass [44]. The pros and cons of using the coffee husk as biomass are this waste is subjected to policy in each country. By implementing pyrolysis there can be the production of better fuel and also by adding the additives produced, leading to improving the process of combustion.

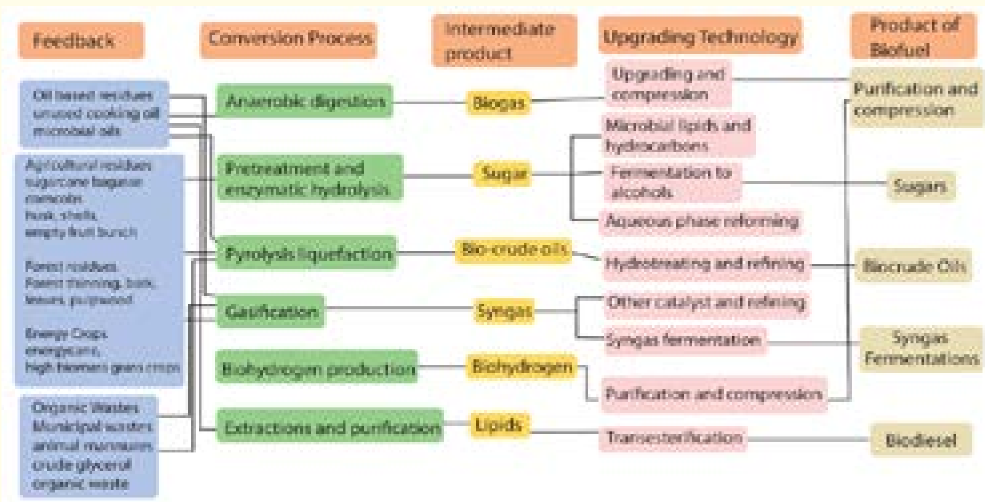

Figure 2: Biowastes, Conversion process and Their Products.

Bioenergy production from anaerobic digestion technology using organic waste

For one effective Anaerobic digestion process, it requires a suitable temperature, ph, and mixture of the correct ratio of the constituents and the tiny particles plays a key role. The process of Anaerobic Digestion includes acidogenesis, acetogenesis, methanogenesis, and hydrolysis [44]. In the hydrolysis process, the substrates are converted to soluble molecules using extracellular enzymes called hydrolase [49]. It also converts carbohydrates, lipids, and proteins to sugars, long chain fatty acids, and amino acids respectively [50]. Step two is bacteria is fermented and transformed into soluble molecules formed at the stage of hydrolysis to lactate, alcohol, carbon dioxide, and volatile fatty acids [51]. The foremost products formed in this step are propionic acid, ethanol, and acetic acid [52]. The step where acetogenesis takes place, the acetogenic bacteria oxidize Volatile Fatty Acids and alcohol to acetic acids and hydrogen. The range of the pH for the AD technology is 6.8-7.4 [53], 6.8-7.5 [54], and 6.8-7.2 [55]. The biogas gained by the AD technology also produces unwanted and dangerous matters like H2S, Si, Carbon monoxide, and Ammonia [56]. It is corrosive and hazardous as well. Since it contains impurities, it has to be purified to increase the yield of methanol. The processes are exhaustive and also expensive [57]. This method yields energy from the products we consider waste.

Future Microbial Applications for bioenergy production

Microorganisms can generate fuel biofuel from biomass and biological wastes. Recently, research has been done to produce fuel from biomass. An example is that many bacteria can convert sugars to ethanol easily and cellulolytic microbes can use plant-extracted substrates. Cyanobacteria and microalgae own the strength to photosynthetically turn the atmospheric CO_2 into biofuel and methanotrophs can utilize methane to produce methanol [58]. Few bacteria like *Geobacter sulfurreducens* and *Shewanella oneidensis* possess particular "molecular machinery", which helps electron transfer from the outer membrane of a microbe to the conductive surface [59], this trait helps in the production of biohydrogen using bioelectrochemical devices. Biofuel that has a more positive net balance energy is contemplated for commercialization. Agricultural waste containing lignocellulose substrates, and plant biomass are considered satisfactory biowastes. Few microbes like S.cerevisiae cannot break down lignocellulose into fermentative constituents [60].

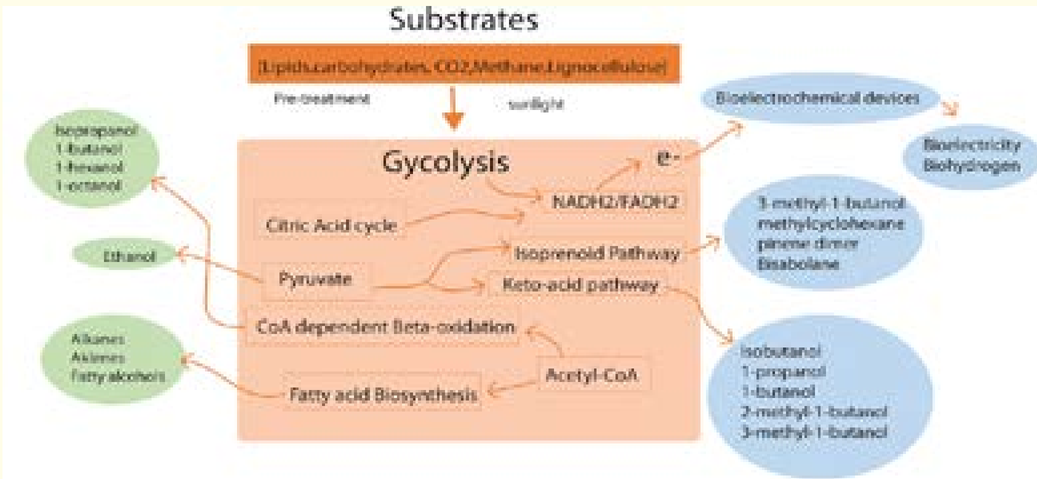

Figure 3: Different ways of production of Alcohol.

Greenhouse gas which is more potent than CO_2 is produced from landfill by the process of anaerobic digestion using biowastes [61]. Methane is oxidized by methanotrophs, by first reducing oxygen to H_2O_2, and then converting methane to CH3OH with the help of methane monooxygenase (MMOs) [62].

There are two ways by which ethanol can be produced in yeast and E.coli. Ethanol production by not using Co- enzyme A is considered a systematic way for the production of ethanol [58]. For microbes that lack metabolic pathways, the imperative gene is injected from the fuel-producing microorganism, converting the non-biofuel-producing organism into producing organism.

These days, bioelectrochemical cells show notable interest in producing biofuel from the biowaste. Microbial electrolysis cells (MECs), and Microbial fuel cells (MFCs) produce biohydrogen and bioelectricity [63]. There are different kind of microorganisms which are called exoelectrogens or electricigens in molecular machinery which help in the production of electrons in the microbial outer membrane, electrons that produce electricity, and hydrogen. MFC can generate a voltage upto 1.2 V to maximum [64].

Exoelectrogen carries redox molecules which help in the electrons being transferred from the outer membrane to the surface [59]. This procedure can be easily performed when inserting the genes encoding the redox proteins into the exoelectrogen's genetic material. Microbial factories are the challenging hurdle for the production of biofuel, generating more fuel with less budget and more efficient fuel.

Applications of biofuels and performance

The liquid biomass fuels have more benefits and grab more awareness, which includes bioglyciene and biodiesel, biomethanol and bioethanol [65]. It can be produced by liquifying the biomass to produce bio-oil, at high pressure and quick pyrolysis [66]. The produced bio-oil is very advantageous for transportation and the energy density is 10 times higher than the biomass [67]. Today, Biomass to fuel is the famous approach and followed by more number of people [68]. As a substitute for petroleum and natural gas, methanol was used for the turbine power generation due to its greater efficiency [69]. DMFC, Direct Methanol Fuel Cell is an important arm part of Fuel Cells (FC), which has a catalyst Pt-Sn/C plays the major part in being an efficient cell [70]. Bioethanol can also be used for the fuel cells in biofuel generation, but depending on the effect of the catalyst in the FC [71]. Efficiency is dependent also on electrolyte membrane [72] and also catalytic oxidation activity. Comparatively, Methanol is a better choice for FC than ethanol. The energy efficiency in combustion is 40.36%, and loss is in the emission of gases [68]. By using the gases that are being wasted should be utilized, which can help in environmental protection benefits [4]. It can be used in the production of hot water or the generation of steam energy.

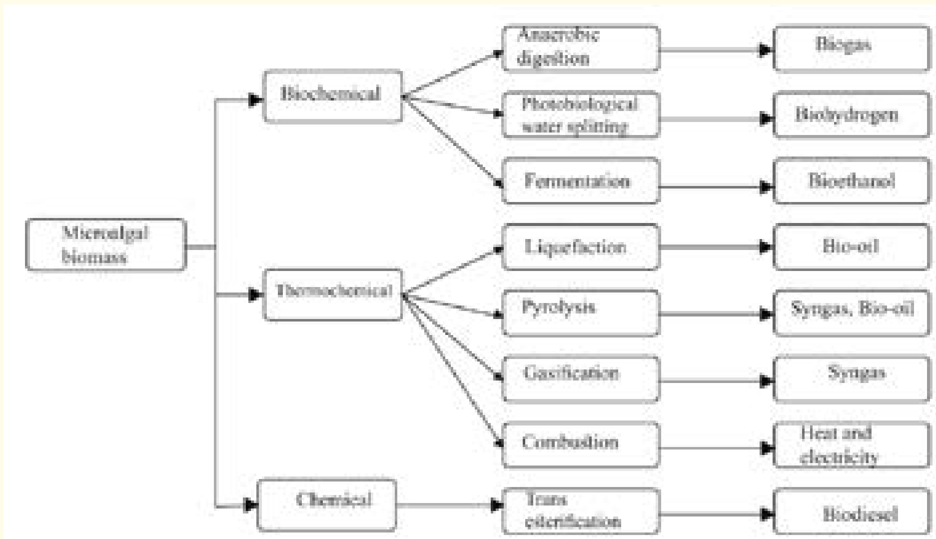

Figure 4: Different ways to produce biofuel using microalgal biomass.

Challenges faced in the production of Biogas

A key challenge is the cost and selection of the methods for biofuel production. An important challenge being the pre-treatment of cellulosic-based bioethanol production to lignocellulose from carbon dioxide. Pre-treatment of the biogas production takes one-third of the cost, which includes hydrolysis and fermentation. All the oils that are produced are not ready to be consumed. Hence, oil extraction has to be done. This mechanical extraction of oil needs the removal of phospholipids and further filtration. In algal biofuel production challenges are huge. From the cost to use of fertilizers and the demand for nutrients.

Conclusion

Benefit of biogas over other energy alternatives is more. Biogas can be easily stored and can be generated when needed. Biogas can be substituted by Fossils. The biogas output can be increased by addition of the required elements with the proper measurements which will also optimize the process. “Waste to landfill” and “Waste to re-use” should be patronized and redirected by the policymakers and the use of low carbon gas should be encouraged for generation of electricity. The support for biogas production should be increased by the government. The notable solution for the exhaustion of GHG emissions, renewable energy production, and waste disposal management is biogas. Due to the target of the government to increase the consumption of renewable energy, industrial residue and agriculture in this country can be regarded as energy renewable sources. The high potential for the generation of electricity is created by residues of biomass. Benefits like economic, political and environmental is given by biomass. The low utilization of biomass is due to lack of expert in optimization of biomass residues, due to this reason industries are unwilling to take the risk of using biomass for generation of power. The main obstacle of using “microbial factories’’ for biofuel production is that we need to generate a huge amount of fuel on a relatively greater efficiency and low budget as contrast to the fossil fuels. Example, for bioethanol to be replaced by petrol, the former should be economical, which is a challenging task. The combustion mechanism of coffee waste, using combustion techniques like pyrolysis. Firstly, they can be an efficiency of 70% for conversion of biomass. Firstly, bio-crude can be used in turbines and feedstock for refineries and engines. Heat rate or temperature net required is increased by pyrolysis. Secondly, to get a more suitable solution for the low sintering process of coffee husks, more research in this area is required. The techniques which help for future research are the use of additives, co-firing with coal should be evaluated on a bigger scale and in actual combustion scenarios, along with the use of additives and an appropriate oven design. Since coffee is rich in nutrients, it acts as the main barrier to using it as a bioenergy as fertilizer. Moreover, storage requires large spaces, which must be free of humidity, since it is a seasonal product. This also suggests the need for logistics and transportation to these centers. Our research also shows the value of coffee by-products which rather than going as a mere waste, can be reused.

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