Biofuels – Scavenger's Hunt for Sustainable Development

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***Abstract*— Today, the world is facing crisis of conventional fuel on one hand and high degree of pollution on the other hand. The biomass from forest and agriculture can serve as a tool for biofuel generation and thereby for sustainable development. The suitability of biomass for the same depends on multiple factors like its chemical composition, availability, cost and energy required as input for fuel generation. The probable modes for green fuel production can be – thermo-chemical, chemical and biochemical. The fuel thus obtained would certainly reduce the CO_2 emissions and also consume some of the organic wastes disposed from various sources as well as the plant materials used for phytoremediation. The paper deals with probable modes in which the biomass can be utilized for generation of green fuel.**

Keywords*— *Pollution, biomass, sustainable development, green fuel

I. INTRODUCTION

Energy consumption has increased steadily over the last century as the world population has grown many folds and industrialization is also enhancing rapidly[1].This has enhanced the use and demands of fuel to a tremendously high level and dragged the world into energy crises. The conventional energy sources that have been in use since the dawn of human civilization are exhausting day by day, moreover have numerous health and environmental impacts [2][3]. Increasing demands for fossil fuels, its limited quantities in reserve, high cost and environmental impacts have threatened the human survival**.**

Such situations have forced mankind to think for alternative fuel for sustainable growth and existence. This search leads us to biofuel generation. Biofuel is basically use of biomass for fuel purposes. This practice is not new to human race. It is being practiced since the invention of fire but in modern times only the mode of utilizing its potentials has changed- liquid and gaseous bio-fuels. The energy thus generated is expected to mitigate numerous environmental problems such as health hazards as well as reduce the problem of solid waste disposal and usage of barren, less fertile soil thereby overcoming the soil erosion problems. Bioenergy is expected to solve the global warming problem to an extent by lowering the carbon dioxide levels generated by use of fossil fuels [4]. Bio-fuel is one of the most promising replacements for fossil fuel since it is renewable and emits less green-house gases as compared to gasoline [5].

Biomass is a term for all organic material that stems from plants (including algae, trees and crops).It is actually the plant material derived from the reaction between CO_2 in the air, water and sunlight, via photosynthesis, to produce carbohydrates that form the building blocks of biomass. Typically photosynthesis converts less than 1% of the available solar energy to stored chemical energy. The solar energy driving photosynthesis is stored in the chemical bonds of the structural components of biomass. If biomass is processed efficiently either chemically or biologically for extracting the energy stored in the form of chemical bond, it can create wonders in the energy field. The subsequent 'energy' product can be used for combustion (estimated to contribute of the order 10–14% of the world's energy supply) and the CO_2 then available can be cycled to produce new biomass via photosynthesis.

II. POTENTIAL FEEDSTOCKS FOR BIOFUEL

All organic matter has chemical energy stored in it but it is easy to use plant material as a feedstock for generation of biofuel due to its ready availability in abundance. These natural resources are renewable and inexhaustible. Various plant materials that can be utilized for the purpose can listed as:

- Woody Perenials
- Herbaceous wild vegetation and grasses
- Crop residue and wastes
- Aquatic macro-phytes /algae
- Dead plant material/ manure

Within this categorization, herbaceous plants can be further subdivided into those with high- and low-moisture contents. Apart from specific applications or needs most of the commercial activities has been directed towards the lower moisture-content types. The suitability of these sources to serve as a potential source however again depends on multiple factors like:

• High yield (maximum production of dry matter per hectare),
• Low energy input for biofuel generation
• Low production cost and nutrient requirements for raising the biomass
• Composition with the least contaminants,
• Easy, simple and economic energy/fuel extraction

Annually, approximately 150 billion tons of biomass in produced all over the world. Biomass contains varying amounts of cellulose, hemicellulose, lignin and a small amount of other extractives. Cellulose is generally the largest fraction, representing about 40–50% of the biomass by weight; the hemicelluloses portion represents 20–40% of the material by weight. Lignin content is higher in woody plant species and lower in the herbaceous ones, although the proportion may slightly vary due to soil quality and environmental conditions. Annually, approximately 150 billion tons of biomass in produced all over the world. Woody plant species are typically characterized by slow growth and are composed of tightly bound fibers, giving a hard external surface, while herbaceous plants are usually perennial, with more loosely bound fibers, indicating a lower proportion of lignin. Herbaceous plant, Aquatic plants and manures are intrinsically high-moisture materials and as such, are more suited to 'wet' processing techniques. The various biomass sources for generating biofuel are shown in Fig. 1.

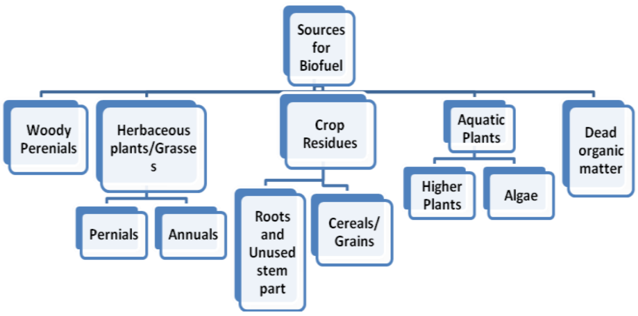

Fig. 1

III. PROBABLE MODES OF BIOMASS UTILIZATION:

Biomass consumption for energy production is being done since the discovery of fire but the modes of utilization have changed from time to time. Earlier, it was limited to direct combustion for production of heat energy but now-a-days it has changed to conversion to liquid or gaseous fuel. Direct combustion of biomass is an ancient practice where energy is released by breaking the chemical bonds with the help of oxidation. The released energy can be utilized for domestic as well as industrial purposes. It can also be used for steam generation and thereby for generating electric power in thermal power plants. Combustion i.e. the traditional use of biomass as fuel has led to several adverse effects on environment and human health. These include irregular rains, green house effect, ozone depletion and so on. Risk of diseases from household solid fuels was found to be the third highest after malnutrition and unsafe water/sanitation, and is responsible for about 420,000 annual excess deaths [6]. Thus, it is the urge of the era to deduce energy from the biomass in some other profitable and less/ non harmful form. Due to harmful impacts of this mode, the modern industrialized countries are more interested in generating green fuel.

Alternatively, biomass can be converted to simpler forms by using thermal/ chemical/biological modes either solitary or in combination to generate green fuel profitably. The nature of pathway used would depend on various factors including efficiency and type of raw material. Depending upon the material and also the type of raw material employed for obtaining the desired product, the mode may be named- Thermo-chemical, bio-chemical or chemical.

These modes can be diagrammatically represented as in Fig. 2.

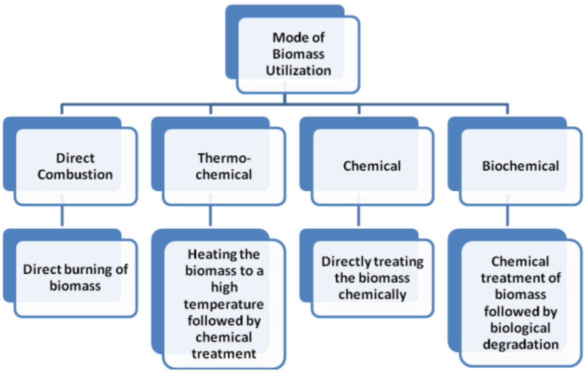

Fig. 2

A. *Thermal/ Thermo-chemical Route:*

The complex organic plant material is treated thermally that is it is exposed to a high temperature to dissociate it into simpler or smaller components. The process is technically called Pyrolysis which involves cracking of the complex organic compounds in absence of oxygen The products include Syngas or synthetic gas which is a mixture of Carbon-di-oxide, carbon monoxide and hydrogen. Such gases can be collected and utilized as fuel for domestic as well as commercial purposes. It can also be utilized for synthesis of synthetic petroleum through Fischer-Tropsch synthesis. This route can be adopted in two ways:

1) Direct Gasification: The biomass is directly gasified by subjecting it to high temperature pyrolysis. The yield thus obtained can be filtered for the removal of fine ash or tars produced as byproducts during conversion. The Syngas thus produced can thereby be liquefied for storage and supply. In Germany, a commercial plant for manufacture of biofuel from wood chips is set up[7].

2) Indirect Gasification: Solid biomass is first converted into liquid biooil in small plant and thereafter it is transported to the gasifiers where it is converted to biogas. The process is also called biomass to liquid conversion (BTL). Bio-oil possesses high density and is a clean liquid that can be easily pumped and stored at ambient temperature. Its easy storage makes this process more suited and beneficial practically. Addition of additives may further enhance the same [8].

Moreover, producing bio-oil from biomass first makes it beneficial in utilizing the co-products/byproducts released where the residue can be utilized for syngas production syngas [9][10].Bio-oils are complex mixtures of oxygenated hydrocarbons, water (from the moisture present in biomass as well as pyrolytic water) and char particles. It can be used as liquid fuel after upgrading it. This is possible by hydrotreating or catalytic cracking [11].

Glycolaldehyde, Levoglucosan and Levoglucosenone are present in high concentration in some bio-oils extracted from of carbohydrates like cellusoses and starches. It can be fractionated by addition of water to it – thus separating it into aqueous and oily phase where all these can be extracted. These compounds can be used to produce browning agents for foods.

Biochar particles present in biooils can also be used as a fuel that can serve as an alternative for coke.

Residual microalgae biomass left after bioethanol production can be used as a feed stock for biogas similar to other agricultural residue uses [12].
The use of microalgae for biomethane production using algal biomass can prove significant because its fermentation is a process of high stability and high conversion rates, making bioenergy production economically efficient.

B. Bio-chemical Route:

An alternative pathway can be hydrolysing the biomass chemically to decompose it into simpler organic compounds like sugars, acetic acid, etc. and there-after fermenting them anaerobically for generation of alcohol (ethanol). Besides this, the plant material rich in sugar content like sugarcane (Brazil) and sugarbeets (Europe) can be directly used for their sugar content. This produces ethanol/bio-ethanol that can be utilized as engine fuel alone or in blended form with gasoline. It is referred to as the first generation ethanol.

The first generation ethanol faces three types of difficulties: Firstly, it consumes a small percent of the biomass as sugar content for bioethanol production, the rest is wasted. Secondly, its utilization for ethanol production increased its price as food article and thirdly the energy used as input for the process was higher or equivalent to the energy generated [13][14].
These shortcomings can be overcome either by using the grain kernals for ethanol production or pyrolysis for production of biooil that can be beneficial in various ways. This would certainly enhance the efficiency of the process in both ways- economically and yield percentage. Cellulose rich materials can also be hydrolysed biochemically for bioethanol production. The process is capable of producing 65 to 70 gallons of ethanol per ton of dry biomass [15]. According to John et al. microalgae can serve as an efficient biomass raw material for bioethanol production[16]. *Chlorella, Dunaliella, Chlamydomonas, Scenedesmus, Arthrospira, and Spirulina* are some of the alga that can be suitable for the purpose due to large starch and glycogen stored in them. The algal biomass is treated for production of first generation bioethanol but this is not an efficient extraction process. To enhance the efficiency of the process oil extraction is done, the residual biomass containing carbohydrates is further utilised for bioethanol production. This process represents a second-generation bioethanol which can prove an alternative to the sugar cane ethanol produced in Brazil and corn or beet ethanol produced in other countries. The process requires pretreatment with a hydrolysis step before fermentation [17][18][19]. The productivity per unit area of microalgae is high compared to conventional processes for the production of raw materials for biofuels, and microalgae represent an important reserve of oil, carbohydrates, proteins, and other cellular substances that can be technologically exploited [20][21].
Ethanol is certainly an efficient fuel with a high octane number and a low tendency to create knocking in spark ignition engines. It is a green low/ non polluting fuel as the oxygen in its molecule permits low-temperature combustion with reduction of CO, NOx emissions and volatile organic compound (VOC) emissions. On the other hand, few drawbacks have also been registered in the account of bioethanol drawbacks include its miscibility with water, aldehyde emissions, compatibility issues with some plastics or metals.

C. Chemical Route:

Animal and vegetable oils both are suitable raw materials for production of Biodiesel. Easy and sufficient availability of vegetable oils make them more suitable for the purpose. Biodiesel generation involves a process called trans-esterification, where esters are produced as a result of reaction of triglyceride groups of the oil with an alcohol, methanol or ethanol. Glycerol is formed as a byproduct and an alkaline catalyst is also required for the reaction. The details of the process are shown in the Fig. 3.

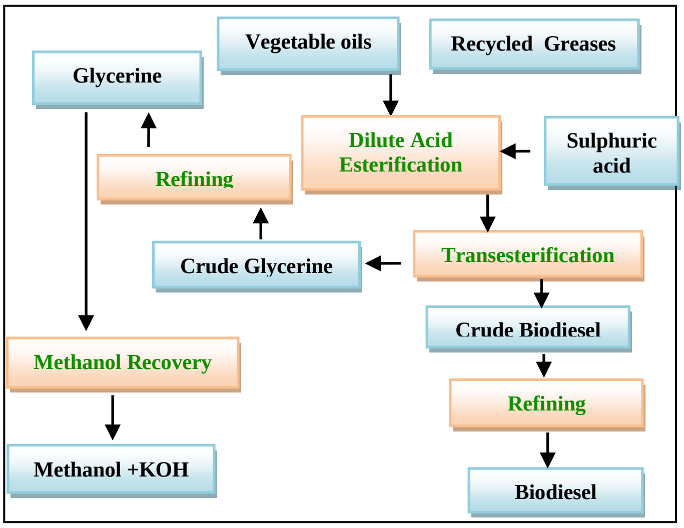

Fig. 3

The most commonly used edible oils are rapeseed oil, soybean oil and palm oil and non-edible oil is jatropha oil[22]. Besides this, numerous non edible oils can be utilized for this purpose but their conversion technology is complex and still requires immense research on it [23][24][25][26]. Algal material grown for phytoremediation of sewage waste water is another option for feedstock for biodiesel production [27].The composition of fatty acids extracted from the algae vary according to the nutritional composition and cultivation conditions[28]. Studies have shown that Chlamydomonas sp. [29] used for phytoremediation of wastewater i.e. removal of nitrogen and phosphorus from waste water can produce18.4% oil and a fatty acid profile suitable for biodiesel production.

Biodiesel-diesel blends can prove to be useful to fuel diesel vehicles with no engine change and produce low sulphur and particulate emissions. Synthetic biodiesel (BTL) is fully compatible with diesel fuel engines.

IV. CONCLUSION

The current review has shown that a number of processes can be employed for conversion of biomass to utilizable fuel forms e.g. bioethanol, syngas, biodiesel and chemicals of commercial and economic value but each process has its own advantages and disadvantages. A lot of research is still to undergo for the best and efficient extraction of green fuel and other byproducts from biomass. Using two or more processes in combination would certainly prove beneficial for economic extraction of energy and other products. This practice would undoubtedly solve the problem of solid waste disposal and serve as an attractive mode to utilize the biomass generated in the process of phytoremediation. At the same time energy generated from such mode would help in mitigating the environmental problems.

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