

Biofuels as a Pathway to Sustainable Development

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Abstract: *The demand for energy has increased globally and the availability of fossil fuel is limited. Added to this, there has been a negative effect on climate due to the emission of greenhouse gases from the burning of fossil fuels. These are the alarming signals to explore unconventional and sustainable energy sources. Biomass energy is becoming popular these days as it is clean and sustainable form of energy. It can potentially solve the problems of waste management and energy security. Growth in industrialization and agricultural sector has witnessed the accumulation of huge biowastes like forest residues, food waste, agriculture crop residues, wood processing residues industrial waste and municipal solid waste (MSW). Biomass from these biowastes have also simultaneously emerged prospective feedstocks for bioenergy production. Production and consumption of biofuel is becoming popular as it will be a novel approach for a sustainable future.*

Keywords: Biomass, biofuel, anaerobic digestion, algal biomass, biobutanol

1. Introduction

Energy is crucial for the development and growth of economy. Non-renewable fuels like coal, oil and natural gas are the primary global resources of energy. Their excessive usage has imposed threats on environment health and economy. The massive use of fossil fuels for heat, electricity and transportation is responsible for the emission of about 70% of greenhouse gas (GHG) globally. It is predicted that more than 420 giga ton emission of carbon di oxide will be responsible for the global rise of temperature of about 1.5^oC, thereby leading to irreversible negative changes in climate. Hence it becomes crucial to attain net zero carbon-di- oxide emission by 2050 to avoid damaging intensification in global temperature. The U.S. Energy Information Administration has projected that the requirement of energy will be nearly two folds by 2050. It becomes imperative to look forward for the energy sources that are renewable and cleaner to address the issues of global environment, economy and energy crisis. Many options of cleaner energy have evolved in past several decades that have been considered as an alternative energy sources of fossil fuels. Chief among them are hydroelectric power, wind, solar, geothermal, nuclear and biomass energy. These novel alternative sources are cost effective, environment friendly and sustainable too. Biofuel is the term given to fuels that are obtained from organic materials such as energy crops, agro residues or waste biomass. Biofuel exist as solid, gaseous and liquid forms. Biofuels have been obtained from wide ranges of cost-effective raw substrates like rice straw, sugarcane bagasse, corn, oil seeds without meddling the food chain. Biomass energy is getting prominence as it has a potential to be a sustainable alternative energy source¹.

Why Biofuels?

Biofuels are contemplated the only predictable, practical and sustainable energy resource. Biomass derived biofuels exists in all three forms viz., solid, liquid or gaseous forms, of which liquid biofuels are able to curtail or substitute the non-renewable petroleum fuels that makes them imperative in global transportation sector. Biofuels have several merits like:

- 1) The issues related to energy and food security are addressed.

- 2) Integrated rural development become feasible as the production of biofuels creates new job opportunities.
- 3) The policies that are affecting multiple sectors are influenced by the production and development of biofuels. Socio economics of the country also gets benefitted.
- 4) Consumption of biofuels improves the combustion and curtails the emission of hydrocarbons thereby addressing the concerns related with containment of carbon emission.
- 5) Bioethanol is a best alternative to gasoline, as it easy to adapt bioethanol to the prevailing engines. Biofuels are cleaner fuels and their octane rating is higher than petrol².

Types of Biofuels

Biofuels are classified into four groups, on the basis of the sources of biomass used for its production

- 1) First-generation biofuels: These biofuels are produced by converting grains sugar to bioethanol vegetable oils to produce biodiesel. Example of such fuels are sugarcane-ethanol, starch-based or corn ethanol. Other examples are Bioalcohols, Green diesel, Biodiesel, Vegetable oil, Bioethers, Biogas. The primary feedstocks for first-generation biodiesel (rapeseed, soybeans, and palm) are all food-based crops. Production of first-generation biofuels is restricted by several issues like food security issues and use of fertile lands for fuel production.
- 2) Second-generation biofuels: Production of second generation (2G) biofuels utilizes non-edible feedstocks like sugarcane bagasse, corn cobs, agro-waste (rice husk, groundnut shell, stalks of wheat, corn and wood, etc.), forest waste, residues of wood processing, sugar beet molasses etc. As all these substrates are non-edible, they give no competition to human food chain. These biofuels are obtained by utilizing lignocellulosic biomasses that are generally agro-industrial residues like rice husk, wheat straw, bagasse, fruit peels, vegetable peels. Sugars present in these residues are converted to ethanol. Forest wastes are also employed for production of biofuels. Similarly, biodiesel can be produced from seeds containing non-edible oils like

Jatropha. Many plants producing seeds that contain non edible oils could be grown in waste lands. Nonedible feedstocks such as jatropha, pongamia, mahua and neem have been broadly explored, and jatropha/ pongamia are observed to be promising feedstocks. Second generation biofuels do not interfere with the food chain nor they have to answer any food security issues unlike first generation biofuels that directly utilizes food material for biofuel production. Cellulosic biofuels, Biohydrogen, Biomethanol, DMF, Bio DME, Fischer-Tropsch diesel, Biohydrogen diesel, Mixed alcohols, Wood diesel are examples of second-generation biofuels.

- 3) Third-generation biofuels: Fuels obtained from algae are known as third generation biofuels. They include algal biodiesel, algal hydrogen and hydrogen produced from conversion of algal biomass. Third generation biofuel mainly emphasis on non-food sources. Algal biomass is comprised of proteins, carbohydrates, and lipids/natural oils and can be used for biodiesel (from algal oils) and bioethanol/ biobutanol production (from algal carbohydrates).
- 4) Fourth-generation biofuels comprise fuels from high solar efficiency cultivations. These fuels are still in their early stages of development. Pyrolysis, gasification, upgrading, solar-to-fuel, and genetic manipulation of organisms to secrete hydrocarbons are some pathways of fourth-generation technology. Green gasoline, Green Diesel, Green aviation fuel are examples of fourth-generation biofuels.

Biofuels are form of bioenergy that are biologically produced from bio-organic matter. Biofuels can be solid, liquid or gaseous. Biofuels can also be classified on the basis of sources of its derivation, according to which biofuels are of 3 types (1) Biofuels of natural origin, (2) Primary biofuels, and (3) Secondary biofuels. Animal waste, landfill gas and vegetables are the organic sources of natural biofuels. Primary biofuels are generally employed as a fuelwood for cooking, heating, electricity production or brick furnace. Secondary biofuels are produced by processing of biomass. Examples of secondary biofuels are biobutanol, bioethanol, biodiesel and biohydrogen³.

Forms of Biofuel

There are many forms of biofuels. Each biofuel has its unique characteristic and plus points. The process of production of these biofuels and the microorganisms involved in these processes also varies from each other. Following are some of the biofuels that are commercially produced and utilized worldwide Bioethanol is a popular biofuel. It has gathered maximum attention amongst the all biofuels. It is a renewable fuel and a suitable option for gasoline. Government of many nations have framed policies to ensure the blending of bioethanol with gasoline in different ratios. Countries like USA, Brazil and China are the global leaders in the production of bioethanol. In US, the consumption of bioethanol exceeds 90% of the complete bioalcohols. Bioethanol can be produced by the fermentation process in which simple sugars are converted by microorganisms into the ethanol at ambient conditions. The raw material employed, determines the cost effectiveness of the process and hence the cost of bioethanol produced. The

production of bioethanol becomes sustainable, eco-friendly and cost-effective if it is derived from lignocellulosic waste biomasses like bagasse, wheat straw, rice straw, peels of fruits and vegetable and other agro forestry or food wastes. For example, pumpkin peel waste has been explored as novel prospective feedstock for bioethanol production. Third generation (3G) bioethanol is procured from algal biomass. These lignocellulosic materials are comprised of cellulose, hemicellulose and lignin. As all these three constituents are tightly associated with each other, they need to be broken down first, so that they are easily accessible for further fermentation. In order to breakdown the complex polysaccharides into sugars, these lignocellulosic biomasses are first pretreated and hydrolyzed through acid/ bases or enzymatic treatment. Sugars liberated out of these processes, that are further utilized by microorganisms to produce ethanol. Microorganisms like *Saccharomyces cerevisiae*, *Pachysolentannophilus*, *Pitchiastipitis*, *Kluveromyces marxianus* etc. are known producers of bioethanol.

Biobutanol is less volatile and hygroscopic in comparison to bioethanol. Moreover, the energy content of biobutanol is also higher than that of bioethanol. These features makes biobutanol a superior fuel in comparison to bioethanol, though its economic production rates are parallel to ethanol. Biobutanol is renewable substitute to gasoline. *Clostridium acetobutylicum*, are solventogenic strains that has potential to produce biobutanol through acetone-butanol-ethanol (ABE) fermentation under anaerobic conditions. In recent times, food waste, predominantly with higher water content has grabbed the attention for the production of biobutanol as feedstock. Biobutanol has been applied as potential transportation fuel for many decades.

Biogas is a second-generation biofuel that is chiefly a mixture of biomethane (~55–75%) and carbon di-oxide (~25– 45%) in anaerobic condition. The feedstock employed for biogas production does not compete with food or food chain. Anaerobic digestion of biomass is a biochemical conversion process that takes place at ambient conditions of temperature and pressure and produces biomethane. Anaerobic microorganisms are involved in this process. Biomethane produced during this process is a promising fuel which has been further converted into bioelectricity. Waste water treatment plants (WWTP) extensively use this popular technology, as this technology is cost effective and has potential to generate revenue by producing energy.

Biohydrogen is a distinguished biofuel as its heat content is highest (143 GJ.ton⁻¹) in comparison to any other available fuels till date and is considered as a neat fuel. It is the only biofuel in which not a single carbon atom is attached. Biohydrogen production occurs during an acidogenesis processes which is biologically mediated. During this process organic compounds are converted into high value-added bio products likely hydrogen and volatile fatty acids. Production of biological hydrogen is eco- friendly, safe and a harmless process. Biomass can be converted to biohydrogen by dark or photo fermentation. It is a microorganism mediated process. Dark fermentation takes place in absence of light in which, biohydrogen is produced from carbohydrate-rich feedstock by anaerobic bacteria. Whereas,

during photo-fermentation the photosynthetic bacteria utilize light energy for the production of biohydrogen from organic feedstocks. Clostridia sp. and Enterobacter are known producers of hydrogen during dark fermentation. These organisms can breakdown the carbohydrates and other intermediates like alcohols and volatile fatty acids into hydrogen. Other feedstocks for biohydrogen production are wastewater from various industries like sugar industry, beverage industry, chemical industry and effluents like distillery industry effluent and palm oil effluent. The hydrogen production can be enhanced by the pretreatment of these feedstocks. Species of Rhodospseudomonas like R. capsulata, R. sphaeroides, R. palustris, R. rubrum, etc. are common photosynthetic bacteria that are employed in the biohydrogen production process.

Biodiesel is a novel alternate source of energy that is not only sustainable but eco-friendly too. This oil is derived when vegetable oils (edible and nonedible), animal fats, and algae is interacted with alcohol. Biodiesel can be used directly or can be blended with diesel for diesel engines. Many plus points are associated with biodiesel like it is renewable and biodegradable fuel with higher cetane value, low content of sulfur and aromatic compounds. Emission of carbon monoxide, particulate matters and unburnt hydrocarbon is very less in biodiesel. Jatropha plant seeds are rich in oil content (40%). It is cultivated and processed for biodiesel production in India. Developed countries employs edible oil seeds such as soybean, groundnut, rape seed, sunflower for biodiesel production. Linseed, palm oil, sunflower oil, coconut oil, canola oil, mustard oil, soybean oil and groundnut oil have successfully been employed as feedstocks for biodiesel production. In order to avoid a conflict of fuel vs. food security, in India nonedible (nonfood) feedstocks are cultivated on the lands that are unsuitable for agriculture (wastelands). Nonedible feedstocks such as jatropha, mahua, pongamia, and neem have been investigated for biodiesel production. Waste cooking oil (WCO) procured from restaurants, food industries, domestic household, etc is a significant feedstock for biodiesel production. The use of these raw materials significantly curtails the environmental hazards and lowers the cost of production significantly. In India, nearly 1.9% of diesel oil could be replaced by biodiesel generated from waste cooking oil. Since both the edible oil and biodiesel markets are anticipated to hike in a coming time, it becomes obligatory to depend on sustainable nonedible feedstocks for the production of biodiesel. Microalgae are rich sources of lipids and fatty acids essential for the food and fuel. The lipid or oily part of the algae biomass can be extracted and converted into biodiesel. Cylinthotheca sp., Nitzschia sp., Schizochytrium sp., Botryococcusbraunii have very high content of oil in their cells and hence are considered as an excellent feedstock for production of third generation biodiesel⁴⁻⁸.

2. Current Research

A number of areas are currently being explored and studied by microbiologists to make the process of biofuel production more efficient. These comprise: 1) Scaling-up the production of microbial cellulase that causes the break-down of celluloses into fermentable sugars. 2) Engineering yeast that

is able to tolerate higher concentrations of alcohol to enhance production of bioethanol. 3) Genetic modification of microorganisms so that they ferment sugars more efficiently to enhance the yields of bioethanol. 4) Optimization of microbial strains so that they can convert sugars into biobutanol as a substitute to bioethanol. 5) Exploring the strains of algae that can potentially produce oils or elseare well adapted for biodiesel production.

3. Conclusion

Biofuels are a renewable source of energy that are generated from an organic matter or wastes, and can play a significant role in curtailing the emission of carbon dioxide. They are globally used as the largest sources of renewable energy. They are eco-friendly as they are clean fuels and are also the solution for the waste management. Biofuels are popular in transport sector, as they are employed in blending with existing fuels such as gasoline and diesel. In the future, they can be predominantly significant to assure decarbonise the aviation, marine and heavy-duty road transport sectors. Novel technologies and processes that generate fuels from inedible crops, waste or forestry products are being explored and developed. Sophisticated biofuels are prospective to become the primary form of biofuels in the future as they can enhance their sustainability.

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