Biofuels

Recently, the increasing concern about declining global supplies of fossil oil from which we derive transportation fuels and a wide range of chemical feedstocks has generated new and urgent interest in expanding the applications of plants so as to produce alternatives to those materials.

Biofuels can be defined as fuels produced from biomass for either transport or burning purposes. They can be produced from agricultural and forest products, and the biodegradable portion of industrial and local waste.

A biofuel is a fuel that is produced through modern biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

The term “**bioenergy**” refers to all types of energy derived from **biofuels**.

Biofuels are fuels derived from matter of a biological origin, or **biomass**.

Biofuels are fuels produced directly or indirectly from organic material (biomass) including plant materials and animal waste.

They may be **solid**, such as fuelwood, charcoal and wood pellets; **liquid**, such as ethanol, biodiesel and pyrolysis oils; or **gaseous**, such as biogas

The biggest difference between biofuels and petroleum feedstocks is **oxygen content**. Biofuels have oxygen levels of 10 to 45% while petroleum has essentially none, making the chemical properties of biofuels very different from those of petroleum. All have very low **sulfur** levels and many have low **nitrogen** levels.

Biomass is an attractive feedstock for three main reasons.

First, it is a renewable resource that could be sustainably developed in the future.

Second, it appears to have positive environmental properties resulting in no releases of carbon dioxide and very low sulfur content.

Third, it appears to have significant economic potential provided that fossil fuel prices increase in the future.

The three main technology conversion routes for converting biomass to biofuel can be grouped into thermo-chemical, physical-chemical and bio-chemical processes.

1- **Thermo-chemical processes** are based on the use of thermal energy to carry out the chemical conversion of biomass to an energy carrier. The most common thermo-chemical technologies include combustion, gasification, pyrolysis and/or carbonization.

   Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen). It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating".

   Carbonization is the term for the conversion of an organic substance into carbon through pyrolysis or destructive distillation. It is often used in organic chemistry with reference to the generation of coal gas and coal tar from raw coal.

2- **Physical-chemical technologies** involve physical and chemical processes such as the production of crude vegetable oil and biodiesel from oilseed crops or from used cooked oil and animal fat.

3- **Bio-chemical conversions** are based on biological processes commonly through the use of microorganisms or enzymes to mediate the conversion of biomass or organic waste materials to produce ethanol or biogas, respectively.

Sources of biomass

Sources of biomass feedstock for energy production include agriculture crops, agricultural and forest residues and other organic waste sources. These various sources of biomass can be grouped under the following categories:

Energy crops: These are agricultural crops that are suitable for bioenergy production.

These include food crops from starch crops such as maize, sugar-based crops such as sugar cane and oil seed crops such as soybean. Non-food crops exclusively grown for bioenergy production are also included in this category, e.g. be grass and woody crops.

Forest growth: This includes potential available woody biomass from forest.

Using woody biomass for energy purposes however may lead to competition with the forest products industry such as timber, boards and paper, etc.

Primary residues from agriculture and forestry: These residues are organic by-products from forestry and agricultural harvesting activities. These usually consist of lignocellulosic material, e.g. small branches, leaves, corn stove, that can be used for energy production.

Secondary residues from processing industry: These residues are produced during the industrial processing of wood and food crops. There is a broad range of residues produced from the various industrial processes each having different characteristics.

For example: the wood processing industry produces sawmill and black liquor which can be used as feedstock for energy production.

Organic wastes: Organic waste such as organic solid waste, wood or used cooking oils comprises a very diverse of biomass that can be used for energy production.

Biofuels Generation

There are three types of biofuels: 1st, 2nd and 3rd generation biofuels. They are characterized by their sources of biomass, their limitations as a renewable source of energy, and their technological progress.

The main drawback of **1st** generation biofuels is that they come from biomass that is also a food source. This presents a problem when there is not enough food to feed everyone. **2nd** generation biofuels come from non-food biomass, but still compete with food production for land use. Finally, **3rd** generation biofuels present the best possibility for alternative fuel because they don't compete with food. However, there are still some challenges in making them economically appropriate.

- ## First generation biofuels

Also known as conventional biofuels, are made from sugar, starch or vegetable oil. First generation biofuels are produced through well-understood technologies and processes, like fermentation, distillation and trans esterification. These processes have been used for hundreds of years in many uses, such as making **alcohol**. Sugars and starches are fermented to produce primarily **ethanol**, and in smaller quantities, **butanol** and **propanol**. Ethanol has one-third of the energy density of gasoline, but is currently used in many countries, including the United States, as an additive to gasoline. **A benefit of ethanol** is that it burns cleaner than gasoline and therefore produces less greenhouse gases. **Another 1st generation biofuel**, called **biodiesel**, is produced when plant oil or animal fat goes through a process called **trans esterification**. This process involves exposing oils with an alcohol such as methanol in the presence of a catalyst. The **distillation** process involves separating the main product from any of the byproducts of the reactions. Biodiesel can be used in place of petroleum diesel in many diesel engines or in a mixture of the two.

- **Second generation biofuels**

The biomass sources for 2nd generation biofuels include wood, organic waste, food waste and specific biomass crops. Fast growing trees such as poplar trees need to undergo a pretreatment step, which is series of chemical reactions that break down lignin, the "glue" that holds plants together, in order to make fuel. This **pretreatment step** involves **thermochemical** or **biochemical reactions** that unlock the sugars embedded in fibers of the plant. After this step, the process to generate plant ethanol likes that of 1st generation ethanol production. Additionally, straw and other forest residues can go through a thermochemical step that produces **syngas** (a mixture of carbon monoxide, hydrogen and other hydrocarbons). Hydrogen can be used as a fuel and the other hydrocarbons can be used as additives to gas oil.

Second Generation Extraction Technology

For the most part, second generation feedstock are processed differently than first generation biofuels. This is particularly true of lignocellulose feedstock, which tends to require several processing steps prior to being fermented (a first generation technology) into ethanol. An outline of second generation processing technologies follows.

Thermochemical Conversion

The **first** thermochemical route is known as **gasification**. Gasification is not a new technology and has been used extensively on conventional fossil fuels for a number of years.

Through gasification, carbon-based materials are converted to carbon monoxide, hydrogen, and carbon dioxide. This process is different from combustion in that oxygen is limited. The gas that result is referred to as **synthesis gas** or **syngas**. Syngas is then used to produce energy or heat.

Wood, black liquor, and other feedstock are used in this process.

The **second** thermochemical route is known as **pyrolysis**. (**Pyrolysis** is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. It involves the change of chemical composition and physical phase, and is irreversible.).

Pyrolysis also has a long history of use with fossil fuels. Pyrolysis is carried out in the absence of oxygen and often in the presence of an inert gas like halogen. The fuel is generally converted into two products: tars and char. Wood and a number of other energy crops can be used as feedstock to produce bio-oil through pyrolysis.

A **third** thermochemical reaction, called **torrefaction**, is very similar to pyrolysis, but is carried out at lower temperatures. The process tends to yield better fuels for further use in gasification or combustion. Torrefaction is often used to convert biomass feedstock into a form that is more easily transported and stored.

Torrefaction is a thermal process to convert biomass into a coal-like material, which has better fuel characteristics than the original biomass.

- **Third Generation Biofuels**

Use specially engineered crops such as algae as the energy source. These algae are grown and harvested to extract oil within them. The oil can then be converted into biodiesel through a similar process as 1^{st} generation biofuels, or it can be purified into other fuels as replacements to petroleum-based fuels.

The term **third generation biofuel** it refers to biofuel derived from **algae**. Previously, algae were part with second generation biofuels. However, when it became apparent that algae are capable of much higher yields with lower resource inputs than other feedstock, many suggested that they be moved to their own category.

Fuel Potential of Third Generation Biofuels

When it comes to the potential to produce fuel, no feedstock can match algae In terms of quantity or diversity. The diversity of fuel that algae can produce results from two characteristics of the microorganism. First, algae produce oil that can easily be refined into diesel or even certain components of gasoline. More importantly, however, is a second property in it can be genetically manipulated to produce everything from ethanol and butanol to even gasoline and diesel fuel directly.

The list of fuels that can be derived from algae includes: Biodiesel, Butanol, Gasoline, Methane, Ethanol, Vegetable Oil and Jet Fuel

Cultivation of Third Generation Biofuels (algae).

Another favorable property of algae is the diversity of ways in which it can be cultivated. Algae can be grown in any of the following ways.

- **Open ponds** – These are the simplest systems in which algae is grown in a pond in the open air. They are simple and have low capital costs, but are less efficient than other systems. They are also of concern because other organisms can contaminate the pond and potentially damage or kill the algae.

- **Closed-loop systems** – These are similar to open ponds, but they are not exposed to the atmosphere and use a sterile source of carbon dioxide. Such systems have potential because they may be able to be directly connected to carbon dioxide sources (such as smokestacks) and thus use the gas before it is every released into the atmosphere.

- **Photobioreactors** – These are the most advanced and thus most difficult systems to implement, resulting in high capital costs. Their advantages in terms of yield and control, however, are unique. They are closed systems.

Third generation biofuels are more energy dense than 1st and 2nd generation biofuels per area of harvest. They are cultured as low-cost, high-energy, and completely renewable sources of energy. Algae are advantageous in that it can grow in areas unsuitable for 1st and 2nd generation crops, which would relieve stress on water and arable land used. It can be grown using sewage, wastewater, and saltwater, such as oceans or salt lakes. Because of this, there wouldn't be a need to use water that would otherwise be used for human consumption.

First generation biofuels represent a step toward cleaner, renewable energy, but they lag behind gasoline because of energy density and economic factors. They also present an ethical problem to use of food crops, as there are millions of people starving around the world.

Second generation biofuels provide some benefits, but the biomass requires pre-treating steps and competes with food crops over arable land in some parts of the world.

Third generation biofuels show the most hope, but plenty of research still needs to be done to reduce production costs and make this type of fuel production commercially viable.

Potential Applications of Biotechnology to Improve Renewable Fuel Production

- Enhanced or engineered microorganisms for fermentation of ethanol, butanol, other fuels.
- Engineered microorganisms or plants to manufacture enzymes used in fuel production.
- Improved algal strains for biofuel production.
- Selected or engineered plant species with favorable traits for use as improved biofuel feedstocks.