Biofuel Generation

The high consumption of fossil fuel mainly has led to climate change and emission of green gases especially CO2. There is a need to generate clean energy and reduce climate change and one of the ways is the use of biomass.

Based on feed stocks and method of production, biofuels are classified in different groups named as first, second, third and fourth generation biofuels.

**First generation biofuel** use edible biomass as starch and sugar which increases the cost of production and causes inefficient utilization of resources and energy spent in cultivating crops.

**Second generation biofuels** are based on more efficient renewable alternatives by utilizing inedible lignocellulosic biomass such as switch grass, sawdust, low priced woods, crop wastes and municipal wastes.

**Third generation biofuel**: aquatic feedstock such as alga biomass used which capture high quantities of CO2 and generate O2 as well as oil, costly, and the biofuel is less stable than that produced from other sources.

**Fourth generation biofuels** - use bioengineered microorganisms such as algae or crops that are genetically altered to consume more CO2 from the environment than they emit when they were consumed (burning).

Biofuels are used to produce different fuels including ethanol, butanol, hydrogen, methane, vegetable oil, biodiesel, gasoline, jet fuel.

**Generations of biofuels.**

**First generation**

First generation biofuels are produced from edible biomass such as starch (from potato, barley, wheat and corn) or sugar (from sugar cane and sugar beet) but concerns arose about using edible crops as feedstocks and impacts on croplands, biodiversity and food supply. The following are considered in the evaluation of edible biomass to produce biofuel:

The biomass chemical composition, energy balance, cultivation practices, emission of polluted gases, availability of cropland, the contribution to biodiversity, cropland value losses, cost of biomass and its transport and storage, competition with food needs and soil erosion.

Bioethanol

Bioethanol fuel is liquid ethyl alcohol (C2H5OH or EtOH) produced from feedstocks such as wheat, sugar beet and corn through fermentation. Primary application is in motor vehicles, used as a transportation fuel in its pure form or by blending it with gasoline in traditional combustion engines. It is normally blended with gasoline at a low percent (10% bioethanol, that is, E10). Use of bioethanol could reduce dependence on fossil fuels and it consumed CO2 in the atmosphere to grow the feedstock crops.

Bioethanol production from corn can be classified into wet and dry milling processes.

Wet mill ethanol process has usually a higher production capacity than the dry process and produces ethanol and some valuable co-products such as nutraceuticals, pharmaceuticals, organic acids and solvents; also, corn oil, corn gluten meal (CGM) and corn gluten feed (CGF) which are animal feeds.

The dry milling process produces ethanol and distillers’ dried grains and soluble (DDGS) which is an excellent livestock feed because it contains proteins, fats and carbohydrates.

**Second generation:**  in this generation, a more sustainable protocol is used to produce biofuels. The feedstock is lignocellulosic material which includes the inexpensive and abundant non edible biomass available from plants.

A wide variety of abandoned materials can be used as biofuel feedstock such as agriculture waste, poplar trees, willow and eucalyptus, miscanthus, switchgrass, reed canary grass, and wood and they mostly consist of plant cell walls whose primary components is polysaccharides (75%).

**Second generation biodiesel**

Several kinds of second-generation feedstocks can be utilized to produce biodiesel such as energy crops, agricultural remains, and wood residual wastage. The most common energy crops for this purpose are *Jatropha, Aleurites moluccana*, salmon oil, Rubber tree *Madhuca longifolia,* tobacco seed, sea mango, and jojoba oil. In addition, waste from cooking oils, non-edible oil crops, restaurant grease, beef tallow, animal fats, and pork lard can also be utilized as biodiesel feedstocks. Animal fats are preferable over first generation feedstocks due to properties such as higher-octane numbers, non-corrosiveness, lack of waste and sustainability. However, the main drawback of this generation of feedstocks is the lack of active technologies for the commercial exploitation of waste generated by biodiesel production. Furthermore, most animal fats possess a high concentration of saturated fatty acids, which increases the transesterification complexity. The main limitation of biodiesel is its comparatively low performance in cold temperatures which hinders their ability to fully replace petroleum transport fuels. Furthermore, bio-safety issues can present in cases of contaminated animal feedstocks.

**Third generation**

Several kinds of microorganisms are used as feedstocks in the third generation of biofuels. Promising microalgae are the most common type for biodiesel production. There are two main classifications for algae based on their size and morphology: macroalgae and micro-algae. One of the most commonly used marine macroalgae is **kelp** which has multiple cells, resembling the roots, stem and leaves of higher plants. In contrast, microalgae which are classified as autotrophic, heterotrophic, and mixotrophic microscopic organisms, exist in both fresh and marine water. Microalgae organisms have excellent potential to produce special chemicals and nutritional products due to their photosynthetic ability. Autotrophic and heterotrophic microalgae differ in the source of the carbon they consume, where autotrophs use inorganic carbon while heterotrophs use organic carbon sources.

Microalgae have several important properties such as requiring less space to grow, high oil content, the ability to grow in both artificial and natural environments, and being eco-friendly. They also possess a unique advantage which is the capability for both oxygenic photosynthesis and hydrogen production. In addition, their growth requirements are simple and limited to light, carbon dioxide and other inorganic nutrients. Microalgae also assist to decrease the CO2 level in the environment because the production of 1 kg of algal biomass consumes around 1.8 kg of CO2. In general, microalgae are considered the best oil provider among various plants. Biofuels produced from microalgae are compatible with presenting fuel engines which eliminate the need for further modification. Microalgae-based biodiesel fuels have similar properties to petroleum-based biofuels such as density, viscosity, flash point, heating value, cold filter plugging point, and solidifying point.

**Third generation bioethanol**

Algae have attracted wide attention as an alternative renewable source for bioethanol production to overcome the problems accompanying first and second generation biofuels. The algae-bioethanol production process is simpler than that of lignocellulosic biomass because it does not require the chemical and enzymatic pre-treatment steps that are necessary to breakdown lignocellulosic biopolymers into fermentable sugars.

**Fourth generation**

In fourth-generation biofuels, genetically modified microorganisms such as microalgae, yeast, fungi and cyanobacteria are utilized as sources. The ability of microorganisms to convert CO2 to fuel through photosynthesis is utilized. The multiple advantages of microalgae such as their high growth rate and oil content and low structural complexity enhance their numerous commercial applications. In addition to genetic modification, some fourth generation technologies involve pyrolysis (in a temperature range between 400 to 600 oC), gasification, upgrading, and solar-to-fuel, pathways. The general purpose of these modifications is to improve the HC yield and create an artificial carbon sink to eliminate or minimize carbon emission.

Cyanobacteria

Cyanobacteria have attracted a lot of attention in bioenergy and biofuel industries. Recently, the genomic revolution has greatly developed metabolic engineering for several photosynthetic organisms. *Synechocystis* was the first photosynthetic organism for which the genome was completely sequenced. *Synechocystis*, which has the ability for both photoautotrophic and heterotrophic growth, is a freshwater, non-filamentous, non-nitrogen fixing organism. The most valuable characteristic of this strain of cyanobacteria as a genetic and physiological case study of photosynthesis are the available genomic, biochemistry, and physiological information.

***Advantages of biodiesel***

Generates fewer pollutant emissions such as COx, SO2, PM and HC compared to diesel

Its production is easier and faster than diesel

It has shown better performance in vehicles due to its higher-octane number

It helps to prolong engine life and minimizes the engine maintenance required

Unlike diesel engine, it does not need additional lubricant to be used

It has a magnificent potential for stimulating sustainable rural development and as a solution for energy security issues

It has a higher cost efficiency than diesel

Unlike diesel, it does not require any drilling, transportation or refinement

Compared with diesel fuel, it has better sulfur content, flash point, aromatic content, and biodegradability

It is safer to handle and less toxic than diesel fuel

It is non-flammable, non-toxic, and it reduces tailpipe emissions, visible smoke and noxious fumes and odors

It does not require any engine modification

It has high combustion efficiency, portability, availability, and renewability

**Disadvantages of biodiesel**

Its combustion generates higher NO2 and NO than diesel

It has a higher pour point and cloud point which may cause fuel freezing and difficulty starting in cold weather