BIOFUELS FROM RENEWABLE RESOURCES

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ABSTARCT

Biofuels have become a popular way to use renewable biomass energy and have emerged as a potentially major alterative to gasoline and diesel transportation fuels derived from petroleum. Interest has been growing in the large-scale application of biofuels to address the global challenges of oil price hikes, greenhouse gas emissions from fossil fuels, global climate change, and shifting away from increasingly scarce and environmentally and politically risky petroleum supplies. This paper provides basic information about biofuels, classification of biofuels, benefits and implications of using biofuels and impacts of biofuel production.

Keywords: Biofuels, Biomass, First generation biofuel, Second generation biofuel, Third generation biofuel

INTRODUCTION

Biofuels are fuels derived from biomass. Biomass is organic matter taken from or produced by plants and animals. It comprises mainly wood, agricultural crops and products, aquatic plants, forestry products, wastes and residues, and animal wastes. In its most general meaning, biofuels are all types of solid, gaseous and liquid fuels that can be derived from biomass. The key advantage of the utilisation of renewable sources for the production of biofuels is the utilization of natural bio-resources (that are geographically more evenly distributed than fossil fuels) and produced bioenergy provides independence and security of energy supply. Utilising agricultural residual and waste substrates as raw materials will minimize the potential conflict between food and fuel and also produced the bio-fertilizer and bio-pesticides. Biofuels produced from lignocellulosic materials generate low net greenhouse gas (GHG) emissions, hence reducing environmental impacts. The various feedstock that can be used for the production of biofuels are cellulosic biomass, sugar and starchy crops, and oil-containing or oil-producing plants. [1]

1. WHY BIOFUELS?

1.1 Alternative source of energy

Nowadays there is a vivid discussion everywhere in the world about alternatives to improve the energy security, save natural resources, and protect the climate. The increasing price of energy, the security of supply, the reduction of greenhouse gases, and the scarcity of oil and gas, urge the use of more and more renewable energy. [2] The interest in biofuels in the industrialized countries, apart from promoting energy security, is also aimed at mitigating the threat of climate change by substituting petroleum fuels. World demand for energy is projected to more than double by 2050 and more than triple by end of century. At the same time, oil prices are rising and fossil fuel reserves are diminishing. Use of biofuels is one such way to protect the environment. Biofuels are considered as one of the most promising options, which can be produced locally and can be substituted for diesel and petrol to meet the transportation sector requirements. Transport is dependent on finite fossil fuels such as oil and petroleum for its energy needs so it is important that we move towards more renewable and sustainable fuels. Added to this, transport is the third largest emitter of greenhouse gases and biofuels can significantly reduce transport’s carbon footprint. [3]

1.1.1 Benefits from the use of biofuels

- Reduced emission of harmful pollutants
- Reduction in greenhouse gas emissions
- Increased employment
- Good fuel properties

2. CLASSIFICATION OF BIOFUELS

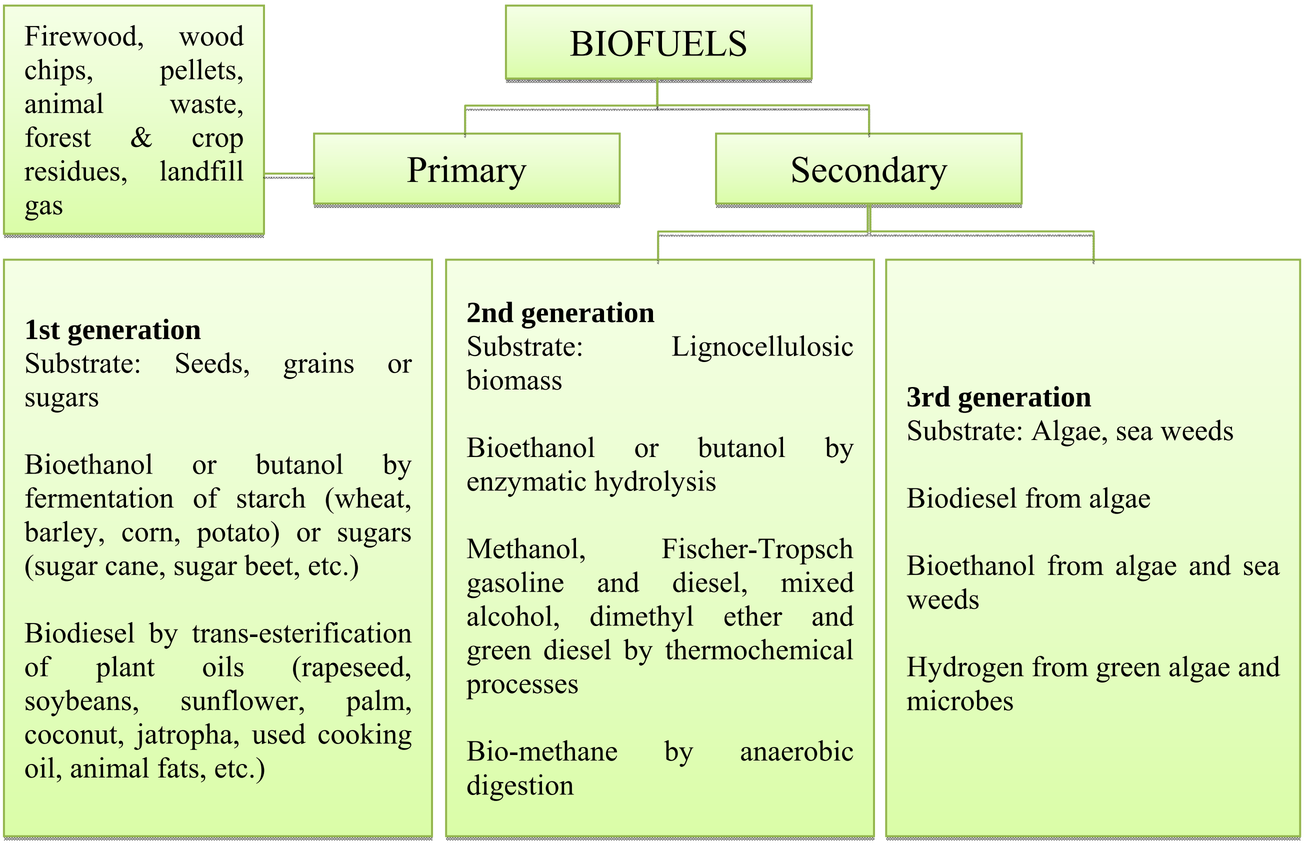

Figure 1. Classification of Biofuels [4]

3. FIRST GENERATION BIOFUELS

The three main types of first generation biofuels used commercially are biodiesel, bioethanol, and biogas of which world-wide large quantities have been produced so far and for which the production process is considered ‘established technology’.

Table 1. Pros and Cons of First generation biofuels [5]

Pros	Cons
▪ Simple and well-known production methods ▪ Scalable to smaller production capacities ▪ Exchangeability with existing petroleum-derived fuels ▪ Experience with commercial production and use in several countries	▪ Feedstocks compete directly with crops grown for food ▪ Production by-products need markets ▪ High-cost feedstocks lead to high-cost production ▪ Reductions in fossil fuel use GHG emissions with current processing methods

3.1. Bioethanol

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Bioethanol is usually produced out of organic based matter with high contents of sugars fermentation by enzymes produced from yeast. The yeasts convert six-carbon sugars (mainly glucose) to ethanol, because starch is much easier than cellulose to convert to glucose. Initially the sugar of raw materials is separated, after which fermentation processes use yeast to convert the glucose into ethanol. The distillation and the dehydration are used as the last steps for reaching the desired concentration (hydrated or anhydrous ethanol) that can be blended with fossil fuels or directly used as fuel. When the used raw materials are grains, usually hydrolysis is used for converting the starches into glucose [6]

Hydrolysis	$[C_6H_{10}O_5]n + nH_2O \rightarrow nC_6H_{12}O_6$ (glucose)	
Fermentation	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	
Energy balance	Glucose → 2 Ethanol + 75 KJ	
	180 gms	2 x 46 gms
	2.82 MJ	2 x 1.37 MJ

3.2. Biogas

Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), and moisture. The production of biogas can be greatly improved by introducing energy-rich co-substrates (e.g., energy crops, green waste) to the anaerobic digester, which can result in a better environmental and economic situation. [7]

3.3. Biodiesel

Biodiesel is produced from oils or fats using trans-esterification and is the most common biofuel. The main source for biodiesel is non-edible oils obtained from plant species such as Jatropha Curcas, rapeseed, soybean etc. The use of biodiesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Biodiesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10 % built- in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. [6]

3.3.1. Manufacturing process for biodiesel

The biodiesel manufacturing process converts oils and fats into chemicals called long-chain mono alkyl esters, or biodiesel. These chemicals are also referred to as fatty acid methyl esters (FAME) and the process is referred to as trans-esterification. Figure 2 provides a simplified diagram of the trans-esterification process. [8]

3.3.2. What makes biodiesel sustainable?

Biodiesel is advantageous over conventional diesel and it contains no hazardous materials and is generally regarded as safe. Table 2 shows the results of the emission tests for pure biodiesel (B100) and 20 per cent biodiesel blend (B20) compared to conventional diesel.

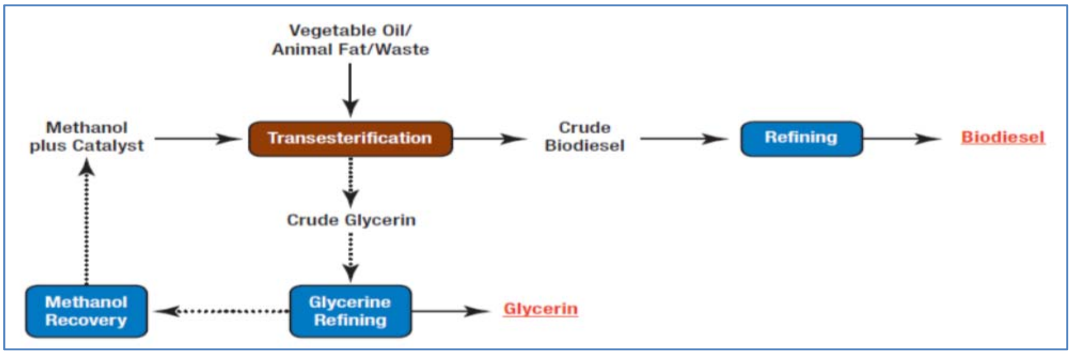

Figure 2. Schematic of biodiesel production by trans-esterification [8]

Table 2. Pure Biodiesel emissions compared 20 % biodiesel [6]

EMISSIONS	B100	B20
Regulated Emissions		
Total Unburned Hydrocarbons	-93 %	-30 %
Carbon Monoxide	-50 %	-20 %
Particulate Matter	-30 %	-22 %
NOx	+13 %	+2 %
Non-regulated Emissions		
Polycyclic Aromatic Hydrocarbons (PAH)	-80 %	-13 %
Nitrated PAH (NPAH)	-90 %	-50 %
Life Cycle Emissions		
Carbon Dioxide	-80 %	
Sulphur Dioxide	-100 %	

4. SECOND GENERATION BIOFUELS

Second-generation liquid biofuels are generally produced by two fundamentally different approaches i.e. biological or thermochemical processing, from agricultural lignocellulosic biomass, which are either non-edible residues of food crop production or non-edible whole plant biomass (e.g. grasses or trees specifically grown for production of energy). The main advantage of the production of second-generation biofuels from non-edible feedstocks is that it limits the direct food versus fuel competition associated with first generation biofuels. The potential feedstock for second generation biofuels production are lignocellulosic feedstock, agricultural, forest residues and biodiesel feedstock. [4]

4.1. Second generation biochemical biofuels

Second generation biofuels such as ethanol and butanol are produced through the biochemical process, whereas all other second generation fuels are produced thermochemically. The basic steps for producing these include pre-treatment, saccharification, fermentation, and distillation. Here enzymes and other microorganisms are used to convert cellulose & hemi-cellulose components of feedstock to sugars before fermentation to produce ethanol. [4]

4.2. Second generation thermochemical biofuels

Second generation thermochemical fuels include methanol, refined Fischer-Tropsch liquids (FTL), and dimethyl ether (DME). Thermochemical production of biofuels begins with gasification or pyrolysis. In this process pyrolysis/gasification technologies produce a synthesis gas ($CO+H_2$) from which a wide range of long carbon chain biofuels such as synthetic diesel or aviation fuel are produced. [3], [4]

5. THIRD GENERATION BIOFUELS

First generation biofuels place an enormous strain on world food markets, contribute to water shortages and precipitate the destruction of the world’s forests. For second-generation biofuels there is concern over competing land use or required land use changes. Therefore, on the basis of current scientific knowledge and technology projections, third-generation biofuels specifically derived from microbes and microalgae are considered to be a viable alternative energy resource that is devoid of the major drawbacks associated with first and second-generation biofuels.

5.1. Biofuel from algae

Microalgae are a potential source of renewable energy, and they can be converted into energy such as biofuel oil and gas. Microalgae are able to produce 15–300 times more oil for biodiesel production than traditional crops on an area basis. Furthermore compared with conventional crop plants which are usually harvested once or twice a year, microalgae have a very short harvesting cycle (≈1– 10 days depending on the process), allowing multiple or continuous harvests with significantly increased yields. [9]

Compared with second generation biofuels, algal fuels have a higher yield: they can produce 30–100 times more energy per hectare compared to terrestrial crops. An integrated production of biofuels from microalgae (Fig. 3) includes a micro algal cultivation step, followed by the separation of the cells from the growth medium and subsequent lipid extraction for biodiesel production through transesterification. Following oil extraction, amylolytic enzymes are used to promote starch hydrolysis and formation of fermentable sugars. These sugars are fermented and distilled into bioethanol using conventional ethanol distillation technology. [10]

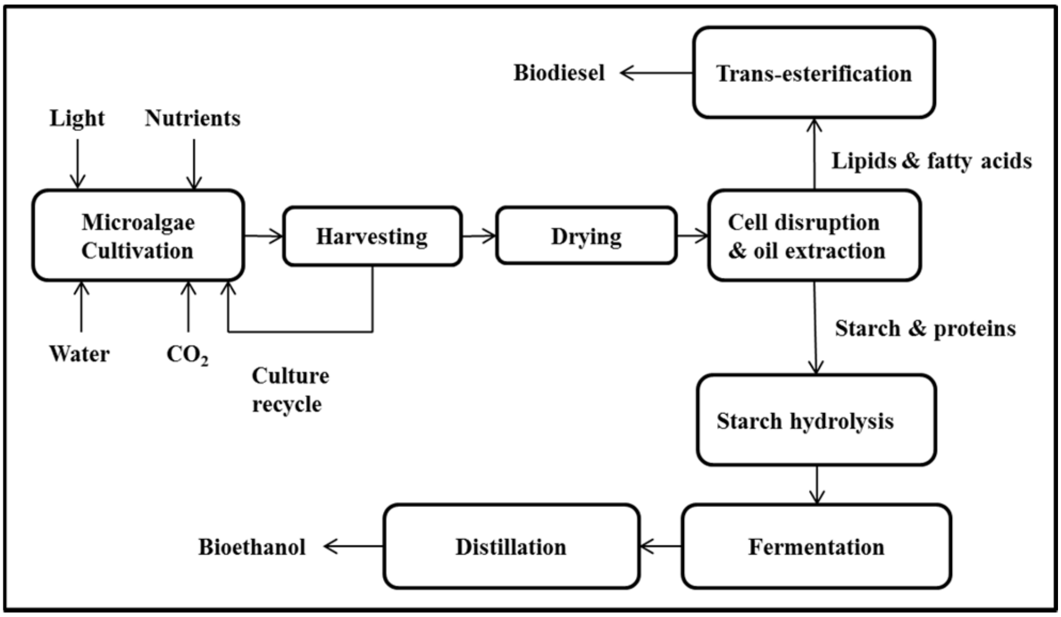

Figure 3. Integrated process for biodiesel and bioethanol production from microalgae [9]

6. IMPACTS OF BIOFUELS PRODUCTION

6.1. Deforestation of rainforests and loss of biodiversity

In order to grow the crops necessary to produce biofuels, additional land must be brought into production. This has led to rainforests being cleared for the sake of plantations. Loss of biodiversity is also another issue that arises when rainforests are being cleared. Another repercussion of deforestation is the destruction of carbon sinks. Rainforests are one of the world's largest carbon sinks. Carbon dioxide is stored in trees and vegetation as they absorb it for photosynthesis and convert it to carbohydrates. The clearing of rainforest plantations results in a sudden release of large amounts of carbon dioxide.

6.2. Problems with water security

Water could be the limiting factor in the production of biofuels. While about 71% of the earth surface is covered in water, only 0.6% is fresh water. The human population is expected to reach seven billion in 2013 and eight billion in 2028. India is already experiencing strains in providing sufficient water for drinking, hygiene and agriculture. [11]

6.3. Biofuels and food prices

The current first generation biofuels rely on food crops such as grains and palm oil which are in direct competition with food, thus putting considerable upward pressure on food prices. Since 2004, the prices of rice, wheat and maize have been rising and been attributed to several factors such as rising energy costs, fertilizer prices and increasing demand for grains to make biofuels.

Wheat production has declined as farmers have focused more on producing oilseeds (e.g., palm oil, rapeseed) and maize for biofuel production. This has led to a depletion of global wheat stocks and a subsequent increase in prices. [11] Using crops for fuel is the driving factor for an increase of food prices. The food price increase in the last few years has been mainly explained as a result of the expansion of biofuels, which reduced the availability of food supply at the international market and increased food prices. [12]

7. BIOFUELS: THE PATH FORWARD

The main driving forces for development of biofuels are energy security, improving trade balances and expansion of the agriculture sector. The recent scientific advances and technological developments in agriculture, biology and chemistry provide win-win possible solutions to the food versus-energy dilemma. These include the development of genetically-improved crops for energy and food production, the production of affordable specialized enzymes, and the ability to artificially simulate natural biological processes such as photosynthesis. Nevertheless, a lot of work still needs to be done to reduce costs, mitigate environmental impacts and biodiversity losses, and minimize the pressure on scarce land resources, particularly on existing productive, arable lands. The production of biofuels from lignocellulose rather than sugars and starches appears to be one of the possible long-term solutions. Research and development efforts are currently focused on efficiently recovering sugars through improved hydrolysis of cellulose and hemicellulose fractions of biomass followed by much better fermentation of sugars into alcohol. Success in this field will result in minimizing the potential conflicts between food and energy production and in maximizing environmental benefits (including greenhouse gas reductions) relative to fossil-fuel use.

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