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PRODUCTION OF BIOETHANOL FROM DIFFERENT RAW MATERIAL

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ABSTRACT

In this production of BIOETHANOL, many raw materials are used in order to prepare the final product. Bioethanol is an example of biofuels which are used as an alternative for the fossil fuels and also used for the travelling purpose. Biofuels are produced over a short span of time from biomass where as formation of biofuels is a very slow process from fossil fuels.

Bioethanol is environmental friendly fuel and cleaner fuel which reduce the emissions of CO_2 and Green House Gases (GHG's) which effect the environment which are mainly produced from the transport sector. Bioethanol is mainly used for road travelling process which is based on alcohol and used as an alternative for petrol.

Bioethanol is produced from raw materials like starch, sugar, lignocellulose materials which produce glucose under several process and following other process gives bioethanol. Bioethanol has advantages as well as disadvantages for the environment.

Bioethanol blended petrol is a mixture of ethanol and petrol which gives more efficiency for the usage for reduction of emission gases at high percentage level. Bioethanol blended petrol is used in many countries which is used as the best alternative fuel.

Bioethanol blended petrol is sometimes harmful to use because it causes accidents which are dangerous for human life. Bioethanol blended diesel is also one of the bioethanol blended fuels also used as an alternative fuel for the travelling purpose.

Key words: Fermentation, Sugar, Starch .Lignocellulose, Ethanol blended fuels

INTRODUCTION

1.0 BIOFUELS

Biofuel is a fuel that is produced over a short time span from biomass, rather than by the very slow natural processes involved in the formation of fossil fuels, such as oil. Since biomass can be used as a fuel directly (e.g., wood logs), some people use the words *biomass* and *biofuel* interchangeably. However, the word *biofuel* is usually reserved for liquid or gaseous fuels used for transportation. The U.S. Energy Information Administration (EIA) follows this naming practice.

Biofuel can be produced from plants or from agricultural, domestic or industrial biowaste. The greenhouse gas mitigation potential of biofuel varies considerably, from emission levels comparable to fossil fuels in some scenarios to negative emissions in others. For an overview of this debate, see the "Biomass" article.

The two most common types of biofuel are bioethanol and biodiesel. The USA is the largest producer of bioethanol, while the EU is the largest producer of biodiesel. The energy content in the global production of bioethanol and biodiesel is 2.2 and 1.5 EJ per year, respectively.

- Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form (E100), but it is usually used as a gasoline additive to increase octane ratings and improve vehicle emissions.
- Biodiesel is produced from oils or fats using transesterification. It can be used as a fuel for vehicles in its pure form (B100), but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles.

In 2019, worldwide biofuel production provided 3% of the world's fuels for road transport, and a very small amount of aviation biofuel. The International Energy Agency wants biofuels to make up 64% of the world demand for transportation fuels by 2050, in order to reduce dependency on petroleum. However, the production and consumption of biofuels are not on track to meet the IEA's sustainable development scenario. From 2020 to 2030 global biofuel output has to increase by 14% each year to reach IEA's goal.

1.1 GENERATIONS:

1.1.1 FIRST GENERATION:

First-generation biofuels are fuels made from food crops grown on arable land. The crop's sugar, starch, or oil content is converted into biodiesel or ethanol, using transesterification, or yeast fermentation. Up to 40% of corn produced in the United States is used to make ethanol, and worldwide 10% of all grain is turned into biofuel. A 50% reduction in grain used for biofuels in the US and Europe would replace all of Ukraine's grain exports.

1.1.2 SECOND GENERATION:

Second-generation biofuels are fuels made from lignocellulosic or woody biomass, or agricultural residues/waste. The feedstock used to make the fuels either grow on arable land but are by products of the main crop, or they are grown on marginal land. Second-generation feedstocks include straw, bagasse, perennial grasses, jatropha, waste vegetable oil, municipal solid waste and so forth.

The use of this class of biofuels is thought to increase environmental sustainability, since the non-food part of plants is being used to produce second-generation biofuels, instead of being disposed. But the use of this class of biofuels increases the competition for lignocellulosic biomass, increasing the cost of producing these biofuels. Although the use of this class of biofuels reduces carbon emissions, their use does not yield net zero carbon emission.

1.1.3 THIRD GENERATION:

Algae can be produced in ponds or tanks on land, and out at sea. Algal fuels have high yields, can be grown with minimal impact on fresh water resources, can be produced using saline water and wastewater, have a high ignition point, and are biodegradable and relatively harmless to the environment if spilled.

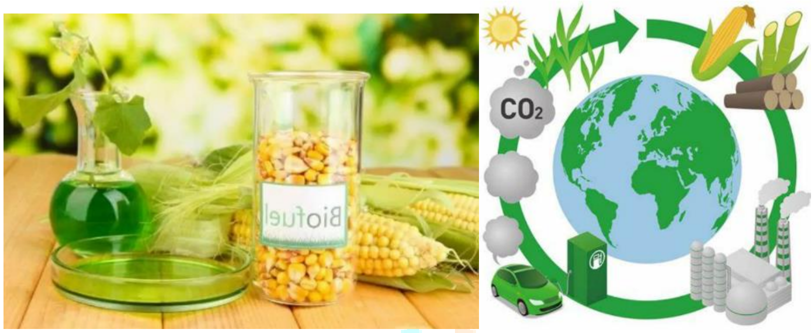
Production requires large amounts of energy and fertilizer, the produced fuel degrades faster than other biofuels, and it does not flow well in cold temperatures. By 2017, due to economic considerations, most efforts to produce fuel from algae have been abandoned or changed to other applications.

1.1.4 FOURTH GENERATION:

This class of biofuels includes electro fuels and solar fuels. Electro fuels are made by storing electrical energy in the chemical bonds of liquids and gases. The primary targets are butanol, biodiesel, and hydrogen, but include other alcohols and carbon-containing gases such as methane and butane. A solar fuel is a synthetic chemical fuel produced from solar energy. Light is converted to chemical energy, typically by reducing protons to hydrogen, or carbon dioxide to organic compounds.

Fourth-generation biofuels also include biofuels that are produced by bioengineered organisms i.e., algae and cyanobacteria. Algae and cyanobacteria will use water, carbon dioxide, and solar energy to produce biofuels. This method of biofuel production is still at the research level. The biofuels that are secreted by the bioengineered organisms are expected to have higher photon-to-fuel conversion efficiency, compared to older generations of biofuels. One of the advantages of this class of biofuels is that the cultivation of the organisms that produce the biofuels does not require the use of arable land. The disadvantages include the cost of cultivating the biofuel-producing organisms being very high.

FIG 1.0 BIOFUELS



LITERATURE REVIEW

2.0 BIOETHANOL

Ethanol is a flammable colourless liquid. When used as an alternative fuel ethanol is referred to simply as Bioethanol. Bioethanol is frequently used as motor fuel or as an additive in gasoline and is an option for more "renewable" energy. Biofuels are liquid or gaseous fuels that are produced from biodegradable fractions of products, remains from agricultural production and forestry, as well as biodegradable fractions of industrial and municipal wastes.

However, ethanol produced from renewable energy sources is one of the most promising biofuels for the future. Although bioethanol fuels can be manufactured using the chemical reaction between ethylene and stream, it is mainly produced through fermentation of sugars derived from crops containing starch, such as corn, wheat, sugar cane, sorghum plants, etc.

It is currently used in the fuel industry as an additive for petrol. It is a highly octane fuel and has replaced lead as an octane enhancer in petrol. Blending ethanol with petrol oxygenates the fuel mixture so that it burns completely and reduces harmful emissions. The most common blend is 90% petrol and 10% ethanol.

Bioethanol is entirely comprised of biological products, and hence the combustion of bioethanol results in cleaner emissions (carbon dioxide, steam and heat). Carbon dioxide is absorbed by plants and processed via photosynthesis to help the plant grow. This cycle of creation and energy combustion means bioethanol could potentially be a carbon neutral fuel source.

Table 1

Specifications of gasoline and ethanol (6)

Specification	Gasoline	Ethanol
Chemical formula	C_nH_{2n+2} (n=4−12)	C_2H_5OH
M/(g/mol)	100-105	46.07
Octane number	88-100	108
ρ/(kg/dm^3)	0.69-0.79	0.79
Boiling point/°C	27-225	78
Freezing point/°C	-22.2	-96.1
Flash point/°C	-43	13
Autoignition temperature/°C	275	440
Lower heating value·10^3/(kJ/dm^3)	30-33	21.1
Latent vapourisation heat/(kJ/kg)	289	854
Solubility in water	insoluble	soluble

2.1 BENEFITS OF BIOETHANOL

Bioethanol has a number of benefits when compared to conventional fuels. Firstly, it is produced from a renewable resource (such as crops). There is therefore little/no net carbon dioxide added to the atmosphere, making bioethanol an environmentally beneficial energy source.

The road transport network contributes a great deal to the release of greenhouse gas emissions into the atmosphere, and with the use of bioethanol, emission rates can be drastically reduced. It is also biodegradable, and less toxic than fossil fuels.

In addition, blending bioethanol with petrol compensates for the diminishing oil supplies across the globe thereby ensuring higher fuel security and avoiding foreign reliance for fuel supply between countries. The rural community will also benefit from the increased demand to grow the necessary crops required for producing bioethanol.

It also reduces the emission of carbon monoxide produced by old vehicle engines and thus improves air quality. Another key benefit of bioethanol is the ease of integrating it with the existing road transport fuel system – bioethanol can be easily blended with conventional fuels (up to 15%) without any need for engine modifications.

2.2 BIOETHANOL PRODUCTION

Different types of biomasses have a potential as raw materials for bioethanol production. Because of their chemical composition, *i.e.*, carbohydrate sources, they mostly form three groups:

(i) sugar-containing raw materials: sugar beet, sugarcane, molasses, whey, sweet sorghum,

(ii) starch-containing feedstocks: grains such as corn, wheat, root crops such as cassava

(iii) lignocellulosic biomass: straw, agricultural waste, crop and wood residues

However, these sugar- and starch-containing feedstocks (first generation) compete with their use as food or feed, thus influencing their supply. Therefore, lignocellulosic biomass (second generation) represents an alternative feedstock for bioethanol production due to its low cost, availability, wide distribution and it is not competitive with food and feed crops.

2.2.1 PRODUCTION FROM SUGAR:

Sugar cane and beet are the most important sugar-producing plants in the world. Two thirds of the world sugar production are from sugar cane and one-third is from sugar beet. They can be easily hydrolysed by the enzyme invertase, which is synthesis by most *Saccharomyces* species. Therefore, the pre-treatment is not required for bioethanol production from the feedstocks containing sugar (sucrose), which makes this bioprocess more feasible than from feedstocks containing starch. Sugar crops need only a milling process for the extraction of sugars to fermentation medium, and here ethanol can be produced directly from juice or molasses.

Sugar cane as a raw material for bioethanol production provides certain advantages, since it is a semi-perennial crop that does not require many agricultural operations that are usually needed for raw crop processing, and its biomass is used for heat and electricity. Sugar cane is less expensive than other raw materials used for bioethanol production due to easier processing and higher productivity. However, many efforts still aim at the improvement of bioethanol production from sugarcane. This includes development of new sugar cane varieties with higher sugar contents and resistance to diseases, larger yield per hectare and greater longevity.

In Europe, sugar production is mainly based on the use of sugar beet as raw material. Raw, thin and thick juice, as intermediate formed during sugar beet processing, as well as high purity crystal sugar, could be converted into bioethanol and/or bio-based products. Raw sugar beet cossetted are also suitable substrates for bioethanol production (31, 32). The use of sugar processing intermediates determines bioprocess configuration, their microbiological stability and transport properties. Sugar syrup and granulated sugar can serve as substrates for bioethanol production during the whole year. Furthermore, they can also serve as precursors for different chemical intermediates or final products (*e.g.*, surfactants; *8*).

2.2.2 PRODUCTION FROM STARCH:

Grain crops (*e.g.* corn, barley, wheat or grain sorghum) and root/tubular crops (*e.g.* cassava, potato, sweet potato, Jerusalem artichoke, cactus or arrowroot) contain large quantities of starch. Isolated native starch from different sources can be used for further conversion into bio-based products and/or the bioethanol production. The residue from starch isolation contains proteins and fibre, which has a great potential for application in food and feed production. The biggest corn starch production is in the USA and it represents more than 80% of the worldwide market. In the USA, corn is a source of over 95% of bioethanol production and the rest is produced from barley, wheat, whey and beverage residues. The grain sorghum cultivating regions in the USA show an increasing interest in bioethanol production from this crop.

Furthermore, the economic viability of bioethanol production from cassava in Thailand was also under investigation. Cassava tubers contain nearly 80% by mass starch and below 1.5% by mass proteins. Pre-treatment of cassava tubers for bioethanol production includes following operations: cleaning, peeling, chipping and drying. After that, the dried cassava chips are used for bioethanol production.

Starch is a mixture of linear (amylose) and branched (amylopectin) polyglucans. The crucial enzyme for starch hydrolysis is α-amylase, active on α-1,4, but not on α-1,6 linkages in amylopectin.

For bioethanol production from starch-containing feedstocks, it is necessary to perform the starch hydrolysis (mostly by α-amylase and glucoamylase) into glucose syrup, which can be converted into ethanol by yeast *Saccharomyces cerevisiae*. This step is an additional cost compared to the bioethanol production from sugar-containing feedstocks. Bacterium *Bacillus licheniformis* and genetically modified strains of bacterium *Escherichia coli* and *Bacillus subtilis* produce α-amylase, while moulds *Aspergillus Niger* and *Rhizopus* sp. produce glucoamylases.

Under anaerobic conditions, yeast *S. cerevisiae* metabolizes glucose into ethanol. The maximum conversion efficiency of glucose into ethanol is 51% by mass. However, the yeast also uses glucose for cell growth and synthesis of other metabolic products, thus reducing the maximum conversion efficiency. In practice, 40 to 48% by mass of glucose is actually converted into ethanol.

2.2.3 PRODUCTION FROM LIGNOCELLULOSE:

Production of bioethanol from the raw materials that contain lignocellulose is attractive and sustainable because lignocellulosic biomass is renewable and non-competitive with food crops. Furthermore, the use of bioethanol obtained from lignocellulosic biomass is related to the considerable reduction of greenhouse gas emission. Lignocellulosic biomass is almost equally distributed on the Earth, compared to the fossil resources, which provides security of supply by using domestic energy sources. It can be obtained from different residues or directly harvested from forest and its price is usually lower than of sugar- or starch-containing feedstocks, which require full agricultural breeding approach.

Raw materials that contain lignocellulose for bioethanol production form six main groups: crop residues (cane and sweet sorghum bagasse, corn stover, different straw types, rice hulls, olive stones and pulp), hardwood (aspen, poplar), softwood (pine, spruce), cellulose wastes (e.g. waste paper and recycled paper sludge), herbaceous biomass (alfalfa hay, switchgrass and other types of grasses) and municipal solid wastes.

The average lignocellulosic biomass contains 43% cellulose, 27% lignin, 20% hemicellulose and 10% other components. Compositional variety of lignocellulosic biomass could be an advantage (availability of more products than obtained in petroleum refineries, and a broader range of feedstocks), but also a disadvantage (need for a large range of technologies) Such heterogeneous structure of lignocellulosic biomass requires more complex chemical processes than uniform and consistent raw materials needed in chemical industry.

Furthermore, harvesting of lignocellulosic crops is usually not possible throughout the whole year, which makes it more difficult for biomass suppliers. Therefore, this problem has to be solved by biomass stabilization in order to be available for long-term storage, and to ensure continuous work of biorefinery throughout the year.

The hydrolysis of lignocellulosic biomass to monomeric sugars is necessary before microorganisms can metabolize them. Acids, alkaline or enzymes usually perform this process. Physicochemical, structural and compositional factors can considerably slow down this process. Therefore, alkaline pre-treatment step is usually necessary to obtain conditions for an efficient enzymatic hydrolysis.

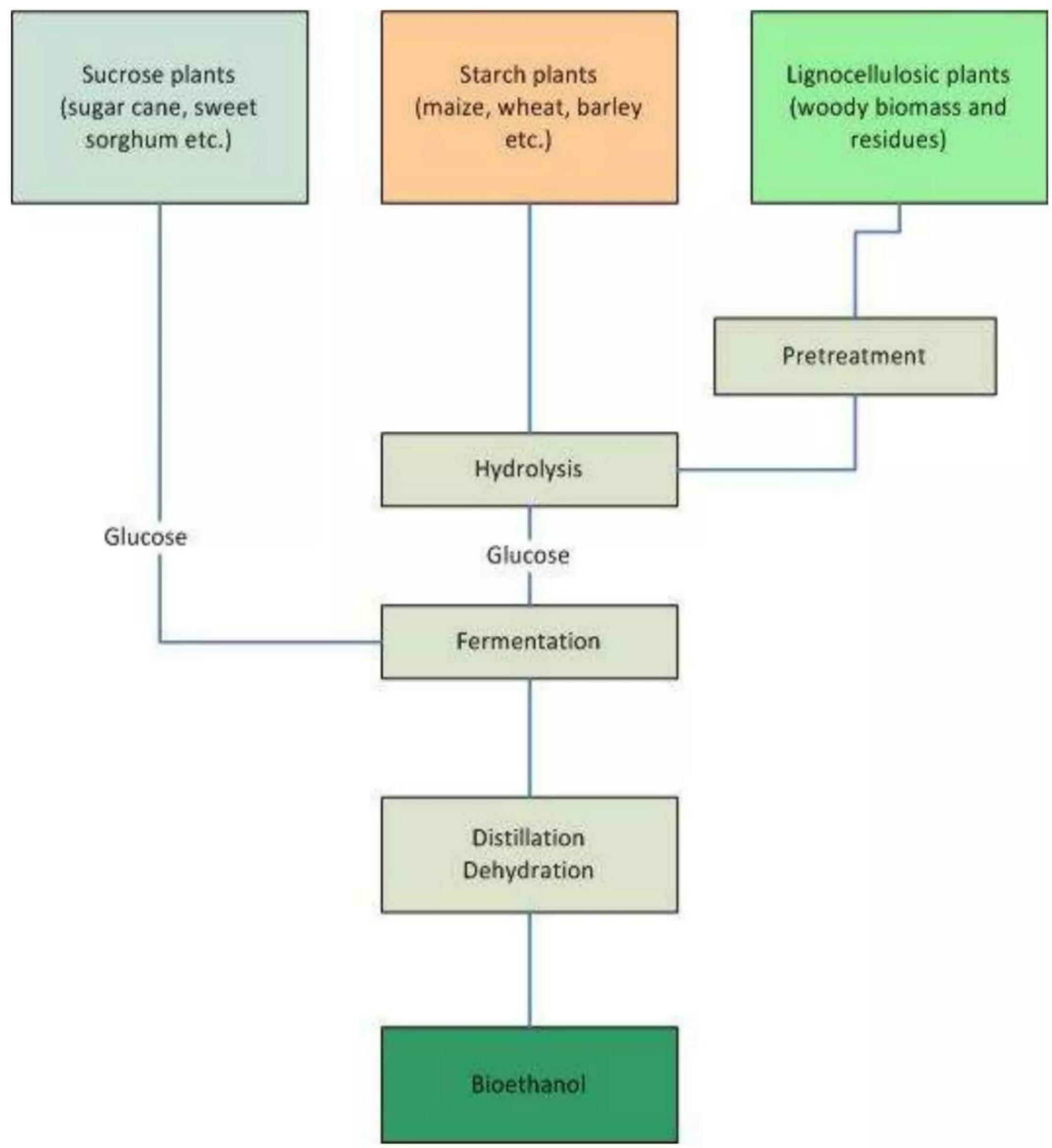


TABLE 2.0 PRODUCTION OF BIOETHANOL

2.3.1 ADVANTAGES OF BIOETHANOL

When it comes to home heating, choosing bioethanol fireplaces offers many advantages. Bioethanol is a carbon-neutral fuel from renewable sources that is easy to obtain and not particularly expensive compared to other forms of heating. This means it is an environmentally friendly choice, but bioethanol has other advantages too.

One of the main things people like about their bioethanol fires is that no smoke is released when the fuel burns. Bioethanol only produces water vapour and a small amount of CO2 when burned (similar to the amount produced by two candles). This means that you do not need a chimney, and so you can have a bioethanol fire anywhere in your home where it would be safe to have a real flame. This also makes bioethanol fireplaces very easy to install, plus, as they leave no ash behind, they are easy to clean and maintain.

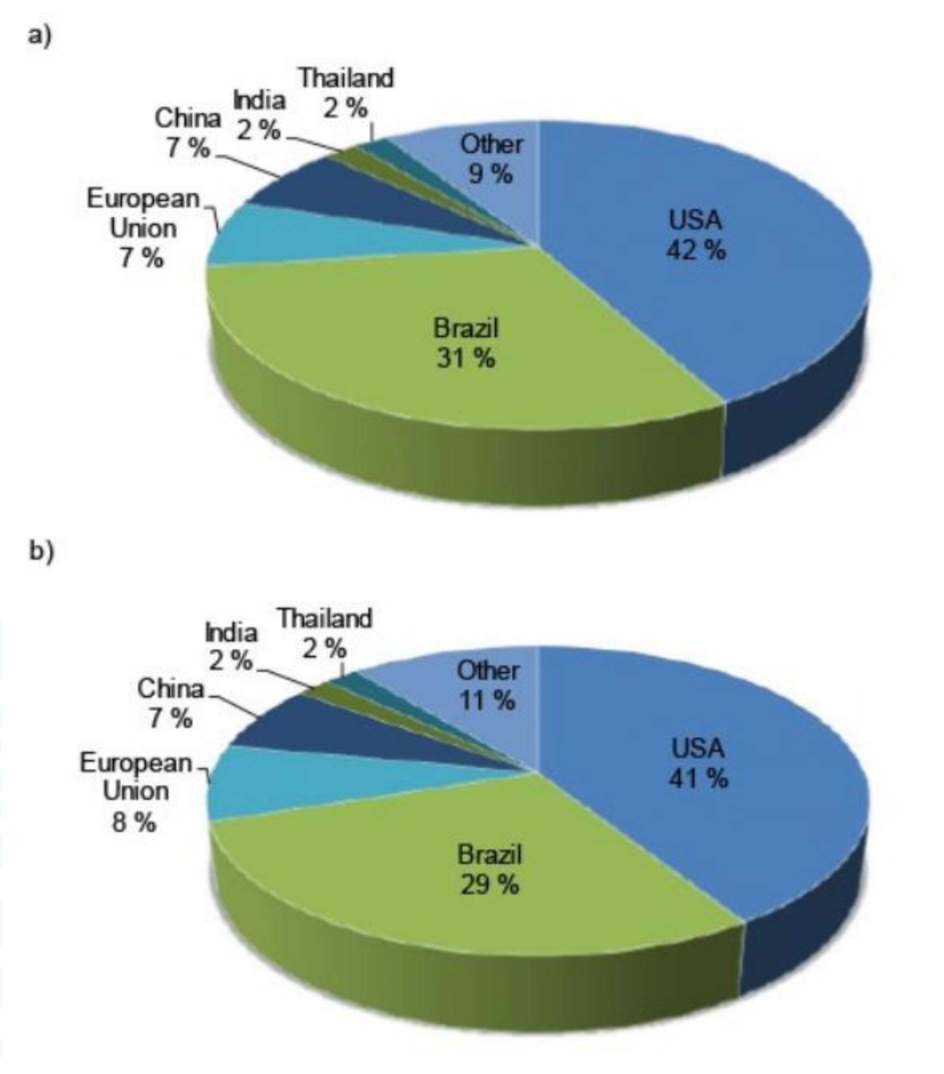
2.3.2 DISADVANTAGES OF BIOETHANOL

Bioethanol is increasingly being used as a fuel for domestic heating, and many people are switching to bioethanol fireplaces. There are many advantages to bioethanol, such as the fact that it is a renewable fuel and the fact that it is flexible in use, allowing you to have fireplaces with real flames without the need for chimneys and vents.

There are only a few drawbacks to bioethanol, but they are still worth considering. One is that it can be more expensive than some other types of fuel, such as wood. However, bioethanol fires are generally much cheaper to buy, build or install, which is also worth considering. If you are economical with your fuel, it can keep costs in line with using other types of heating, too.

Another concern is that as bioethanol becomes more widely used, especially in countries where it is used as an alternative to petrol in many vehicles, food prices will rise as more land is used to grow crops for fuel. This is a concern, but it is hoped that agriculture for fuel will reach sustainable levels without this happening. In the UK, cars containing 100% bioethanol are not used, and globally the electric car market may eventually replace bioethanol as a more environmentally friendly alternative.

FIGURE 2.2 PREDICTS OF THE WORLD BIOETHANOL PRODUCTION (a) AND CONSUMPTION (b) BY 2024



ETHANOL BLENDED FUELS

3.0 ETHANOL BLENDED PETROL

An ethanol blend is defined as a blended motor fuel containing ethyl alcohol that is at least 99% pure, derived from agricultural products, and blended exclusively with petrol. A blend is a mixture of two or three different substances. Several common fuel mixtures are used in the world like ethanol blended petrol and ethanol blended diesel. Ethanol blended petrol is a mixture of hydrous or anhydrous ethanol with petrol. Ethanol fuel mixtures consists of "E" numbers which include the percentage of ethanol in the mixture. In E85, mixture contains 85% ethanol and 15% petrol.

3.1 ETHANOL BLENDED PETROL PROGRAMME(EBP)

The Ethanol Blended Petrol Programme was launched in 2003 with an aim to promote the use of renewable and environmentally friendly fuels and reduce India's import dependence for energy security.

- Starting with 5% blending, the government has set a target of 10% ethanol blending by 2022 and 20% blending (E20) by 2030.
- The programme is implemented in accordance with the National Policy on Biofuels.
- Under this programme, oil marketing companies (OMCs) will procure ethanol from domestic sources at prices fixed by the government.
- Till 2018, only sugarcane was used to derive ethanol. Now, the government has extended the ambit of the scheme to include foodgrains like maize, bajra, fruit and vegetable waste, etc. to produce ethanol.
- This move helps farmers gain additional income by selling the extra produce and also broadens the base for ethanol production in the country.

3.2.1 ADVANTAGES OF ETHANOL BLENDED PETROL

- The auto fuels we commonly use are mainly derived from the slow geological process of fossilisation, which is why they are also known as fossil fuels. Ethanol in comparison is a biofuel, that is, it is primarily derived from processing organic matter (hence, it is a biofuel). In India, ethanol is largely derived from sugarcane via a fermentation process.
- Since it is a plant-based fuel, ethanol is considered renewable.
- Since ethanol is high in oxygen content, engines using ethanol blends combust fuel more thoroughly reducing vehicular emissions. Hence, this process will also help reduce the country's carbon footprint.
- Mixing 20 percent ethanol in petrol can potentially reduce the auto fuel import bill by a yearly $4 billion, or Rs 30,000 crore.
- Another major benefit of ethanol blending is the extra income it gives to farmers. Ethanol is derived from sugarcane and also foodgrains. Hence, farmers can earn extra income by selling their surplus produce to ethanol blend manufacturers.

3.2.2 DISADVANTAGES OF ETHANOL BLENDED PETROL

- Availability of sufficient feedstock on a sustainable basis: Current regulations in the country allow production of ethanol from sugarcane, sugar, molasses, maize and damaged foodgrains unfit for human consumption. Further, surplus rice with FCI is also allowed. Some states have demanded that rice procured by state governments be allowed for ethanol production. However, there is the issue of diverting foodgrains from human consumption to ethanol production when hunger and malnutrition are still problems faced by many in the country.
- Production Facilities: Ethanol production facilities have to be augmented if the goals of 20% blending by 2030 are to be achieved. Currently, ethanol production is largely confined to the sugar producing states. Sugar mills, which are the key domestic suppliers of bio-ethanol to OMCs, were able to supply only 57.6% of the total demand. The mills also do not have enough financial stability to invest in biofuel plants.
- Price uncertainty: The prices of both ethanol and sugarcane are fixed by the government leading to concerns among investors regarding the price of bioethanol.
- Availability of Ethanol: Ethanol is not equally available all over the country. This leads to an increase in transportation and logistics costs. Moreover, handling and storage of ethanol are also risky as it is a highly flammable liquid.
- Challenge for vehicle manufacturers: Vehicle manufacturers must work with vendors to develop automobile parts compatible with ethanol. They should work on engine optimisation for higher ethanol blends.
- Environmental clearances: Currently, ethanol production plants/distilleries fall under the "Red category" and require environmental clearance under the Air and Water Acts for new and expansion projects. This often takes a long time leading to delays.

CONCLUSIONS

Production of biofuels from renewable feedstocks has captured considerable scientific attention since they could be used to supply energy and alternative fuels. Bioethanol is one of the most interesting biofuels due to its positive impact on the environment. Currently, it is mostly produced from sugar- and starch-containing raw materials. However, various available types of lignocellulosic biomass such as agricultural and forestry residues, and herbaceous energy crops could serve as feedstocks for the production of bioethanol, energy, heat and value-added chemicals. Lignocellulose is a complex mixture of carbohydrates that needs an efficient pre-treatment to make accessible pathways to enzymes for the production of fermentable sugars, which after hydrolysis are fermented into ethanol.

Despite technical and economic difficulties, renewable lignocellulosic raw materials represent low-cost feedstocks that do not compete with the food and feed chain, thereby stimulating the sustainability. Different bioprocess operational modes were developed for bioethanol production from renewable raw materials. Furthermore, alternative bioethanol separation and purification processes have also been intensively developed.

This paper deals with recent trends in the bioethanol production as a fuel from different renewable raw materials as well as with its separation and purification processes.

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