Vol. 5 Issue- 3, November 2024 (e-ISSN: 2582-8223)

Liquid Biofuels: Sustainable Fuel for Agricultural Machinery

P. Vijayakumary[1*], J. Gitanjali[2], R. Parimala devi[3], P. Meenakshi[4] and D. Ramesh[5]

[1*, 3]Associate Professor, [2]Teaching Assistant, [4]Assistant Professor, [5]Professor and Head, Department of Renewable Energy Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore – 641 003

ARTICLE ID: 28

Introduction

Agriculture is a vital sector in India, contributing around 18% of the GDP, but the sector faces significant challenges including rising energy prices, environmental degradation and the urgent need to reduce greenhouse gas emissions. In 2020, agricultural sector consumed about 10% of Indian total energy mainly from fossil fuels. This is not only expensive, but also accompanied by price volatility and supply. To solve these problems, the Indian government has established an ambitious goal of promoting biofuel. The National Biofuels Policy targets a 20% blend of biofuels with petrol and diesel by 2030, signaling a commitment to reduce the dependency on fossil fuels while supporting sustainable agricultural practices. India produces around 500 million tonnes of agricultural biomass annually, which can be converted into liquid biofuels such as biodiesel and bioethanol through transesterification and fermentation technologies, providing a renewable fuel for agricultural machinery such as tractors, harvesters, irrigation pumps, etc. Biofuels offer a range of environmental, social and economic benefits, including reduced emissions of harmful pollutants; reduced greenhouse gas emissions; increased employment; improved energy security, especially in rural areas; reduced dependency on oil imports; and better fuel properties for vehicles.

Liquid biofuels

The two most common liquid biofuels used as an alternative to petroleum-based fuels are bioethanol and biodiesel. Bioethanol can be produced from any feedstock that contain significant amounts of sugar or substances that can be converted to sugar, such as starch or cellulose whereas biodiesel production utilizes vegetable oils, animal fats, and recycled greases as its main raw materials. These liquid biofuels can be synthesised by various routes (Fig.1.).

Fig.1. Routes of Liquid Biofuel production from Biomass

Bioethanol production process

The production of bioethanol through fermentation is a widely used process for converting biomass into bioethanol. Sugars can be easily fermented whereas starchy materials have to be converted into sugars, which can then be converted into bioethanol. Lignocellulosic materials can be converted to sugar, though with more difficulty than conversion of starch. While various microorganisms like mushrooms, bacteria, and yeast can facilitate fermentation, the specific yeast *viz., Saccharomyces cerevisiae* is frequently employed for fermenting glucose into ethanol. The fermentation process typically takes place in large tanks or bioreactors, where the microorganisms are maintained in a controlled environment with optimal temperature, pH, and nutrient levels. The fermentation broth is then cooled and separated to produce a clear liquid containing ethanol, which is then purified and dehydrated to produce anhydrous ethanol.

Fermentation of sugar to bioethanol

The process of conversion of sugar into ethanol begins with the harvesting of sugar rich raw materials, such as sugarcane or sugar beets, which are then processed to extract the sugars, primarily glucose. Yeast is then added to the sugar solution to induce fermentation. Yeast converts the sugars into ethanol and carbon dioxide. After fermentation, the mixture is distilled to separate ethanol and concentrate. Further purification can be implemented to achieve high ethanol purity due to fuel or industrial applications. This method is efficient and leverages the natural metabolic processes of yeast to transform biomass into biofuel.

Bioethanol from starchy materials

Another potential raw material of ethanol production is starch, a complex carbohydrate composed of a long chain of glucose molecular molecules. Saccharification process has to be done before fermentation process to convert starch into ethanol. This is a process to break the starch into a simpler glucose unit. This conversion typically begins with hydrolysis, where starchy materials are mixed with water to create a slurry. The slurry is then stirred and heated to break down the cell walls of the starch granules, making it easier to access the glucose chains. During the heating process, certain enzymes, such as amylase, are introduced that catalyze the hydrolysis of starch by breaking the chemical bonds that connect the glucose units. As the starch is converted into glucose, it becomes fermentable by yeast, allowing for the subsequent fermentation process to occur.

Cellulosic materials to bioethanol

In addition to sugar and starch, cellulose can also be converted into ethanol, but the process of producing ethanol from cellulosic biomass is more complex than from sugars or starches. Cellulosic materials, often referred to as lignocellulosic biomass, consist of three main components: lignin, hemicellulose, and cellulose. Before fermentation into ethanol can occur, these materials must first be converted into five- and six-carbon sugars. Lignin serves a critical structural role in plants, providing rigidity and support. As a result, woody plants, such as trees, tend to have higher lignin content than herbaceous plants like grasses. Unfortunately, this lignin encases cellulose and hemicellulose, making them less accessible for conversion. While cellulose consists of long chains of glucose molecules similar to starch, its structural configuration differs, making it more resistant to hydrolysis. Hemicellulose, on the other hand,

JUST AGRICULTURE
multidisciplinary e-Newsletter

is composed of various sugar molecules, with its composition varying depending on the plant source.

There are three primary methods for converting cellulose into ethanol: acid hydrolysis, enzymatic hydrolysis, and thermochemical processes. Acid hydrolysis is the most widely used method, utilizing acids to break down cellulose into sugars. Sulphuric acid is the most commonly employed acid due to its low cost and effectiveness. Each of these processes presents unique challenges and efficiencies, influencing the overall viability of cellulosic ethanol as a sustainable energy source.

Thermochemical conversion of biomass to bioethanol

The production of ethanol from biomass is a complex process that involves several steps, including preparation of the feedstock, gasification, and conversion to ethanol. There are two main ethanol production processes that use thermochemical reactions: hybrid thermochemical-biological systems and fully thermochemical processes. The first process, a hybrid system, combines the benefits of thermochemical and biological processes to produce ethanol: in this process, cellulosic biomass material is first thermochemically gasified to produce syngas, a mixture of hydrogen and carbon monoxide. The syngas is then bubbled through specially designed fermenters where microorganisms capable of transforming the syngas under specific processing conditions are introduced. These microorganisms ferment it to produce bioethanol, which is then captured as a product.

In contrast, a fully thermochemical process doesn't use any microorganisms: instead, the biomass is first thermochemically gasified to produce syngas, which is then passed through a reactor containing a catalyst. The catalyst converts the syngas into ethanol, which is collected as a product. This process is simpler and more efficient than the hybrid process, but it also has limitations. For example, catalysts used in fully thermochemical processes may need to be replaced frequently, increasing production costs.

Methods to produce anhydrous bioethanol

Distillation is the most commonly used method to produce anhydrous ethanol. Ethanol is first separated from the fermentation broth by centrifugation or filtration. The resulting liquid is then distilled to separate the ethanol from water and other impurities. Ethanol is then purified and dehydrated using a combination of distillation, rectification and molecular sieving technologies. *Molecular sieve dehydration* uses a type of zeolite called a molecular sieve to remove water from ethanol. The molecular sieve is designed to selectively adsorb water molecules, leaving behind ethanol. *Activated carbon dehydration* uses activated carbon to remove water from ethanol. Activated carbon is designed with a large surface area and high adsorption capacity, which can effectively remove water from ethanol. *Vacuum Distillation* reduces the boiling point of the ethanol, making it easier to separate from water. *Adsorption dehydration* removes water from ethanol using adsorbents such as silica gel or alumina. The adsorbents are designed to selectively adsorb water molecules, leaving behind ethanol. *Pressure Swing Adsorption technology* uses a combination of adsorbents and pressure swings to separate the ethanol from water and other impurities. The reverse osmosis membrane is designed for the selective difference in water molecules, leaving ethanol behind in *Reverse osmosis*. *Freezedrying* technique to remove water from ethanol which involves freezing the ethanol and then removing the water by sublimation. In *Membrane separation method*, ethanol water is removed using membrane that aims to refuse the hydraulic molecule, and is left behind ethanol. The choice of method depends on the type of raw material used, the scale of production and the desired purity level.

Biodiesel production process

Biodiesel is a fatty acid ethyl or methyl ester and has properties similar to petrodiesel. The selection of fats or oils for biodiesel production involves both process chemistry considerations and economic factors. When it comes to process chemistry, the main distinguishing factor between different fats and oils is the quantity of free fatty acids present in the triglycerides. Transesterification is the widely used method for biodiesel production which involves the replacement of an alcohol from one ester with another. Transesterification of triglycerides results in the formation of fatty acid alkyl esters and glycerol. A layer of glycerol settles at the bottom of the reaction vessel. Diacylglycerols and monoacylglycerols are formed as intermediates in transesterification reactions. The most common catalyst materials used to convert triglycerides into biodiesel are sodium hydroxide or potassium hydroxide. Most basic catalyst systems use vegetable oils as the feedstock. Acid catalyst is more commonly used for feedstock with high free fatty acids. The acid catalyst contains sulfuric acid and phosphoric acid. Once the process is complete, the acid needs to be neutralized, which can be done when a base catalyst is added to convert the remaining triglycerides.

Catalyst based transesterification process

Oil is heated in the transesterification reactor to attain the reaction temperature and the catalyst and methanol mix is loaded in the reactor. During the reaction, the system is stirred. After the reaction process, in some processes, the esters and glycerol are first separated by allowing the reaction mixture to settle in the reactor, while in other processes the reaction mixture is pumped to a settling vessel or separated using a centrifuge. The alcohol is removed from the glycerol and ester streams using an evaporator or flash unit. The ester is neutralized, washed thoroughly with warm, slightly acidic water to remove methanol and residual salts, and then dried. The prepared biodiesel will be transferred to the storage tank and glycerol is sent to the refining section.

Non-catalytic transesterification processes

Non-catalytic transesterification processes do not use a catalyst to drive the transesterification reaction, but instead rely on the presence of a solvent and parameters *viz.*, temperature and pressure conditions to carry out the reaction. In recent years, non-catalytic transesterification processes have attracted much attention due to their potential to reduce energy consumption, production costs and environmental impact.

(i) *Supercritical fluid extraction method* uses high pressure carbon dioxide or other solvents to extract fatty acid esters from vegetable oils and uses flash or distillation to separate the esters from glycerin and other impurities which enables the production of good quality biodiesel with low levels of impurities. (ii) *Ultrasound assisted transesterification* uses high frequency ultrasonic wave to destroy triglyceride and alleviate the reaction. This method can operate at relatively low temperatures and pressures, reducing energy consumption and environmental impact. (iii) *Mechanochemical transesterification* is another non-catalyzed transesterification process that uses high energy mechanical forces to break down triglycerides and facilitate the reaction. (iv) *Enzyme assisted transesterification* process that uses enzymes such as lipase to catalyze the reaction. The enzyme is added to the reaction mixture and reacts with the triglycerides and alcohols. (v) *Microwave assisted transesterification* uses microwave energy to heat the reaction mixture and accelerate the transesterification reaction. Microwave energy is used in combination with a solvent or other additive to speed up the reaction.

Conclusion

Usage of biodiesel and bioethanol in agricultural machineries, increases fuel efficiency, reduces fuel consumption and cuts emissions. Besides protecting the environment, biofuels also reduce the cost of farming operations and increases the competitiveness in the market. In addition, the use of biofuels can increase energy security, reduce dependence on fossil fuels, and contribute to local production of renewable energy sources. Also, the production of biodiesel and bioethanol creates new jobs in rural areas and contributes to the economic development of the region. Overall, the use of biodiesel and bioethanol in agricultural machineries is an important step towards a more sustainable and environmentally friendly agricultural sector. By accepting these alternative fuels, farmers can reduce their carbon marks, improve profits, and contribute to more stable food systems.

References

https://mopng.gov.in/files/uploads/NATIONAL_POLICY_ON_BIOFUELS-2018.pdf

Peter Mckendry. (2002) Energy production from biomass (part 2): conversion technologies. Bioresource Technology. 83: 47 -54.

Pugalendhi, S., R. Shalini, J. Gitanjali and P. Subramanian. (2019). Introduction to renewable sources of energy. TNAU, Coimbatore

Rai, G.D. (2002). Non-conventional Energy Sources. Khanna Publishers, New Delhi, India.