International Research Journal of Education and Technology

Peer Reviewed Journal . ISSN 2581-7795

OPTIMIZATION OF TRANSESTERIFICATION PARAMETERS FOR ENHANCED BIODIESEL YIELD FROM MAHUA OIL

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Abstract - In the past few decades, major researchers focus on fuel consumption and emission reduction. Due to volatile fossil fuel price and depletion, there is a growing demand for the alternative fuels. Alternative fuel like biodiesel is green energy, which is derived from vegetable oils. Utilization of green energy in more efficient manner is a need of research. This research work is about the production of biodiesel from jatropha oil. Other oils can also be used for the production, but jatropha was chosen because it is not edible therefore, it will not pose a problem to humans in terms of food competition. Before the transesterification process was carried out, some basic tests such as free fatty acid content, iodine value, and moisture content were carried out. This was done so as to ascertain quality yield of the biodiesel after the reaction. The production of the biodiesel was done with standard materials and under standard conditions which made the production a hitch-free one. The jatropha oil was heated to 60°C, and a solution of sodium methoxide (at 60°C) was added to the oil and stirred for 45 minutes using a magnetic stirrer. The mixture was then left to settle for 24 hours. The result shows that the product meets the set standard for biodiesel. The focus is to study its performance and emission characteristics of biodiesel under various engine loading conditions.

Keywords: Transesterification, Mahua oil, Bio-diesel

I. Introduction

There is a continuous search for renewable sources of fuels due to the rate of depletion of fossils. The term biofuel is used to define fuels that are obtainable from plants or animals. Being a renewable source, it is gaining attention all over the world today. Biofuel is defined as fuel comprising of mono-alkyl esters of long fatty acids derived from vegetable oils or animal fats. These fuels could be either in the form of vegetable oils or animal fats that have been transformed by chemical or natural processes for use in powering various engines. Biofuels are obtained from renewable energy sources such as biological materials from living organisms and can also be obtained from biodegrade waste. Hence, the term biomass is used to describe the sources of biofuels. These are wastes from plants and animals that are capable of being used as fuels in their original form or with little modification. These wastes can also be used in production of fibres and chemicals that are essential to our daily lives. The term biofuel is not the same with fuels from fossils, the major difference between biofuels and fossil fuel is in their carbon content and the amount of emission they give off when burnt.

1.1 ENVIRONMENTAL FATE AND BEHAVIOR

Biodiesel is predicted to partition primarily to the soil and, to a lesser extent, water and sediment. Shorter chain FAMEs are expected to be more mobile in soil. Biodiesel is considered readily biodegradable. Typically 80% or more will degrade in 28 days in laboratory testing. Due to faster biodegradation than petroleum diesel, biodiesel is expected to have less environmental migration than petroleum diesel; however, biodiesel may delay the biodegradation of petroleum hydrocarbons such as benzene and toluene. Biodiesel has limited volatility but some evaporation will occur; if spilled, it is lighter than water and may produce a sheen on the surface. Biodiesel is not expected to bioaccumulate as FAMEs are metabolized and excreted if uptake occurs.

Biodiesel is often considered to improve energy security and reduce the impact of fuel on climate change. However there are concerns about the impact of biodiesel when its life cycle is considered. The potential impact of using biodiesel rather than conventional diesel was investigated using a life cycle assessment (LCA) of rapeseed biodiesel. Biodiesel leads to reduced fossil fuel use and is likely to reduce the impact of transport on climate change. However it was found that the impact of biodiesel towards other categories, i.e. land use and respiratory inorganics, was greater than petroleum diesel. Therefore biodiesel production should be carefully managed to mitigate its impact on the environment.

21st European Symposium on Computer Aided Process Engineering Vasiliki Kazantzi, ... Mahmoud M. El-Halwagi, in Computer Aided Chemical Engineering, 2011, Biodiesel is emerging as one of the most attractive forms of biofuel. In addition to its role in reducing greenhouse gases and enhancing sustainability, biodiesel can also have a favorable impact on the properties of petro-diesel upon blending. Moreover, in blending diesel and biodiesel fractions, there is a need in estimating the resulting properties, and hence the quality, of diesel/biodiesel mixtures. However, since properties of biodiesel and diesel/biodiesel mixtures are influenced by the characteristics, availability and seasonality of the feedstock used for biodiesel production, as well as processing conditions, diesel and biodiesel blends may differ considerably in terms of their resulting properties and quality features. These issues are addressed by the paper using a property-integration optimization-based framework.

Dr. Rudolf Diesel, invented the Diesel Engine in 1895, used only bio- fuel in his engine. His statement was “The application of vegetable oils as engine fuel may seem insignificant today, but such oils may become in course of time, as important as products of petroleum and coal of present time”. The above prediction came true today as more and more biodiesel is being used all over the world. Scientists E. Duffy and J. Patric conducted the process of Transesterification of a vegetable oil in the early 1853, years before the first diesel engine became operating. On August 31, 1937, G. Chavanne of the University of Brussels (Belgium) was given a patent for the transformation of vegetable oils for their uses as fuels. The use of biodiesel was recognized much earlier and became technically relevant only after the energy crisis in the year 1973 and afterward. Vegetable oils have high viscosity due to large molecular weight and bulky molecular structure. High viscosity liquid fuels affects the flow properties and also sprays atomization, vaporization, air/fuel mixture formation. Higher viscosity has an adverse effect on the combustion of vegetable oils in diesel engines. Temperature greatly affects the viscosity of vegetable oils.

1.2 Biodiesel

Figure 1. Biodiesel

Biodiesel is made from animal fats or vegetable oils, renewable resources that come from plants such as atrophy, soybean, sunflowers, corn, olive, peanut, palm, coconut, safflower, canola, sesame, cottonseed, etc. Once these fats or oils are filtered from their hydrocarbons and then combined with alcohol like methanol, diesel is produced from this chemical reaction. These raw materials can either be mixed with pure diesel to make various proportions or used alone. Despite one's mixture preference, biodiesel will release a smaller number of pollutants (carbon monoxide, particulates and hydrocarbons) than conventional diesel, because biodiesel burns both cleanly and more efficiently. Even with regular diesel's reduced quantity of sulfur from the LSD (ultra-low sulfur diesel) invention, biodiesel exceeds those levels because it is sulfur-free.d.

1.3 Conventional with Biodiesel

Chemically, vegetable oils are very different from the conventional diesel fuels, because they consist of glycerol fatty acid esters (triglycerides). These compounds are bigger in size than the ones found in the petroleum diesel. The operation of diesel engine with vegetable oils for a long period of time causes problems such as deposits in the engine, filter clogging, carbon residues Biodiesel. Chemically, vegetable oils are very different from the conventional diesel fuels, because they consist of glycerol fatty acid esters (triglycerides). These compounds are bigger in size than the ones found in the petroleum diesel. The operation of diesel engine with vegetable oils for a long period of time causes problems such as deposits in the engine, filter clogging, carbon residues in the injection system, and agglomeration in the lubricant oil, due to the high viscosity of vegetable oils and their polymerization tendency. In order to avoid the above problems, scientists tried to create a renewable fuel with lower viscosity properties than the vegetable oils. Thus, they turned to fatty acid esters with lower viscosity and properties close to petroleum diesel. This was the birth of biodiesel.

1.4 BIODIESEL PRODUCTION

Biodiesel production consists of the following basic steps:

- ✓ Collection and preparation of the raw materials
- ✓ Chemical production of biodiesel
- ✓ Separation of final products—distribution in the market

The raw materials include seeds of various oil mill plants, animal fats, or even used fried oils or bad quality oils unsuitable for edible use. There are two ways for the oil extraction from the raw material. The removal of oil could be achieved with the use of a solvent (e.g., hexane), or with mechanical means (sometimes a combination of the above two methods is used). The mechanical removal of oil is mainly used in raw materials with high oil content.

Hexane is separated from the oil, recovered, and then recycled as much as possible. Free fatty acids that may exist Biodiesel production consists of the following basic steps:

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1.5 Engine Operation

Biodiesel improves fuel lubricity and raises the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts from wearing prematurely. One unintended side effect of the federal regulations, which have reduced allowable fuel sulfur to only 15 ppm and lowered aromatics content, has been to reduce the lubricity of petroleum diesel. To address this, the ASTM D975 diesel fuel specification was modified to add a lubricity requirement (a maximum wear scar diameter on the high-frequency reciprocating rig [HFRR] test of 520 microns). Biodiesel can improve the lubricity of diesel fuel, even at very low levels. The amount of biodiesel required depends on the specific properties of the diesel fuel, but 2% biodiesel is almost always sufficient for adequate lubricity. Important Features of Bio-diesel.

II. Methodology & Objective

2.1 Methodology

For the treatment of oil, the methods used are Pyrolysis, micro- emulsification, dilution and transesterification. Among all the methods transesterification reaction is a most preferred method as found in the literature [1, 7, 8], as it is a less expensive way of transforming vegetable oil to biodiesel. Transesterification is also known as alcoholysis. It is the removal of a lcohol from an ester by another alcohol same as the process of hydrolysis. This process is mainly used to reduce the viscosity of oils (triglycerides). Triglycerides are easily transesterified in the presence of the alkaline catalyst at atmospheric pressure and at a temperature of 60°C to 70ºC with an excess of methanol. The transesterification works well when the initial oil is of high quality. But, quite often low-quality oils are used for biodiesel preparation. In which the free fatty acid content is above 1%, difficulties arise by the formation of soap which promotes emulsification during the water washing stage. FFA content above 2% the process becomes unworkable. In this investigation, the theoretical value of %FFA for Mahua oil is quite higher. So, the two-step process of esterification in the presence of acid catalyst and Transesterification in the presence of a basic catalyst is carried out to reduce the %FFA to less than 1 which makes it comparable to Diesel.

2.2 Objectives

The objective of mahua biodiesel is to produce biodiesel fuel from the seeds of the mahuacurcas plant. This plant is known for its ability to grow in arid and marginal lands, making it a potentially sustainable source of biodiesel. The main goals of mahua biodiesel production include reducing dependence on fossil fuels, promoting renewable energy sources, and potentially providing economic benefits to communities where mahua is cultivated. Additionally, mahua biodiesel aims to mitigate environmental impacts associated with conventional diesel fuel use, such as greenhouse gas emissions and air pollution.Biodiesel is fatty acid ethyl or methyl ester made from virgin or used vegetable oils (both edible and nonedible) and animal fats. The main commodity sources for biodiesel in India can be nonedible oils obtained from plant species such as Jatropha curcas (Ratanjyot), Pongamia pinnata (Karanj), Calophylluminophyllum (Nagchampa), Hevcabrasiliensis (Rubber), etc. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend or can be used in its pure form. Just like petroleum diesel, biodiesel operates in compression ignition engine; which essentially require very little or no engine modifications because biodiesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure.

III. Extraction of Oil & Bio Diesel

4.1 Process & Extraction Mahua Oil

Harvesting Mahua Seeds: Mahua seeds are collected from the mahua tree (Madhuca longifolia). These seeds are typically gathered when they fall from the tree or are manually harvested from ripe fruits.

Cleaning: The collected seeds are cleaned to remove any dirt, debris, or other impurities.

Drying: After cleaning, the seeds are dried to reduce moisture content, which helps prevent spoilage during storage and facilitates the extraction process.

Crushing or Grinding: The dried mahua seeds are crushed or ground to break them down into smaller particles, increasing the surface area for oil extraction.

Oil Extraction: There are various methods for extracting oil from mahua seeds, including mechanical pressing, solvent extraction, and cold pressing. Mechanical pressing involves applying pressure to the crushed seeds to squeeze out the oil. Solvent extraction involves using solvents like hexane to dissolve the oil from the seeds. Cold pressing involves pressing the seeds at low temperatures to retain the nutritional quality of the oil.

Filtering: The extracted oil may undergo filtration to remove any remaining solids or impurities, resulting in a cleaner and clearer oil.

Storage: The extracted mahua oil is then stored in suitable containers away from light, heat, and moisture to maintain its quality until further processing or use.

IV. CHARACTERIZATION OF OIL & BIO-DIESEL

As per standard methods, the physical and chemical properties of Mahua oil are determined in Department of Chemical Engineering, B.I.T., Mesra – Ranchi. Table 1 shows the comparison between Pure Mahua oil properties with Diesel. The properties like Kinematic viscosity, flash point, fire point and density of Mahua oil is higher than diesel. The calorific value of the oil is observed to be lower than diesel. Viscosity is determined in Redwood Viscometer and other properties like flash and fire point is determined by using Cleveland Open cup apparatus in the above-mentioned laboratory. Determination of calorific value is carried out in a Bomb calorimeter in Aerospace Engineering Department, B.I.T., Mesra. The density of Mahua oil is found to be 0.87g/cc at 20°C which is higher than diesel. The Flash and Fire point are found to be 360°C and 368°C respectively which are very higher than Diesel. The % FFA (Free Fatty Acid) content of oil is determined by the method of titration.

Property	Unit	Pure Mahua Oil	Diesel
Density at 20°C	g/cc	0.87	0.80
Kinematic Viscosity at 40°C	Cst	51.85	3.80
Calorific Value	MJ/Kg	38	42
Flash Point	°C	360	68
Fire Point	°C	368	73
Pour Point	°C	13	-18
Cloud Point	°C	12	-15
Acid Value	mg KOH/mg	38	0.35
Free Fatty Acid	%	19	0.17

Table1: Comparison of Pure Mahua oil and Diesel characteristics.

V. Result & Comparison with Conventional Fuel

Mahua oil can be converted into biodiesel through a process called transesterification. Biodiesel produced from mahua oil is renewable and can be used as a substitute for conventional diesel fuel.

It's considered environmentally friendly because it produces lower emissions compared to fossil fuels. However, the feasibility and efficiency of biodiesel production depend on various factors such as the quality of the oil, the conversion process, and economic considerations.Transesterification Process: Mahua oil, like other vegetable oils, undergoes transesterification to convert it into biodiesel. In this process, the oil is mixed with an alcohol (typically methanol or ethanol) and a catalyst (usually sodium hydroxide or potassium hydroxide). This reaction breaks down the oil into fatty acid methyl esters (FAME), which is the chemical name for biodiesel, and glycerin.

Properties of Mahua Oil Biodiesel: Biodiesel derived from mahua oil has properties similar to conventional diesel fuel. It has a high cetane number, which indicates good ignition quality, and it typically has lower sulfur content, resulting in reduced emissions of sulfur oxides when burned.

Feedstock Availability: Mahua trees (Madhuca longifolia) are native to India and are cultivated for their oil-rich seeds. The availability of mahua oil as a feedstock for biodiesel production depends on factors such as cultivation practices, harvest yields, and regional climate conditions.

Economic Viability: The economic viability of producing biodiesel from mahua oil depends on factors such as the cost of feedstock, processing technology, government policies and incentives, and market demand for biodiesel. In some regions, biodiesel production from mahua oil may be economically competitive with conventional diesel fuel, especially when considering environmental benefits and sustainability.

Challenges and Considerations: Challenges in producing biodiesel from mahua oil include ensuring consistent feedstock quality, optimizing production processes to maximize yield and efficiency, and addressing potential environmental and social impacts associated with increased demand for mahua oil as a biodiesel feedstock.

VI. CONCLUSION

The important parameters like Density, Calorific Value, Viscosity, Flash Point, Fire Point, Pour Point, Cloud Point and %FFA are determined in this study. As evident, properties of Mahua oil are comparable to diesel except viscosity and %FFA which is later reduced and made comparable to diesel by two-step process of esterification and transesterification. Since the oil is indigenously produced from seeds of Mahua trees which are found abundantly in rural areas of India, its application in C.I. engine will reduce the degradation of the environment and shall also reduce our dependency on foreign imports.

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