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The Economics of Biodiesel Production: A Review

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Abstract
Biodiesel is a renewable fuel that is usually narrowly defined as esters of lower alcohol and fatty acids, where the fatty acids are derived from vegetable oil, animal fat, or tallow. Biodiesel is sometimes called fatty acid methyl esters (FAME).
The chemistry involved in biodiesel production, pollution as well as advantages of biodiesel over fossil fuel will be discussed.
Key words: Biodiesel, Economics, Chemistry, Renewable energy.

Introduction
Renewable fuels are increasingly being used to replace fuels from non – renewable sources. Biodiesel development was driven by the need to;
(A) Increase the security of energy supply for the transportation sector by having a renewable source at hand to replace the non – renewable source when they eventually become extinct.
(B) Have a fuel for the diesel combustion engine that is environmentally friendly.
(C) Provide the world with a fuel that reduces health and security risk.
(D) Provide the customer with a reliable fuel at a reasonable cost – benefit ratio.
Generally, renewable fuels are produced to reduce greenhouse gas emissions, improve combustion of fuels, and to extend supplies of fossil fuels, although their production may also be used to subsidize the production of agricultural commodities and improve the balance of trade for countries that produce little fossil fuel.
The world Energy policy is targeted at promoting the use of biofuels as a replacement of fossil fuels having certified biofuels as having the potential to reduce global warming and being renewable.
The International Energy Agency (IEA), an international agency formed with the aim of improving cooperation and information exchange between countries that have national programs in bioenergy research, development and deployment affirmed that by mid – century, biofuels could be providing over one quarter of all transport fuel, including Jet fuel (Tulloch, 2011).
The restrictive nature of the definition of biodiesel as esters of lower alcohol and fatty acids notwithstanding, diverse potential for using bio – components for fuels abound.
Biodiesel is produced from animal – based fats and vegetable oils which are composed of fatty acid chains that are chemically bounded to one methanol molecule. Most animal fats and vegetable oils are predominantly triglycerides (TGs). Each triglyceride is composed of three long – chain fatty acids of 8 to 22 carbon atoms attached to a glycerol backbone. Although Triglycerides may be used as fuels without chemical modification, these compounds increases fuel viscosity, are poorly combusted, and tend to prematurely foul upper cylinder engine parts. However, chemical processes of converting fats and oils to alkyl esters of mono alcohols are now in common use to produce a fuel with lower viscosity that may be used as direct replacement of diesel fuel. Five types of common chains are present in animal fats and vegetable oil;
Fig 1: common chains present in animal fats and vegetable oil.
Linoleic: R= - $(CH_2)_7CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH_3$ (18:3)
Oleic: R = - $(CH_2)_7CH{=}CH(CH_2)_7CH_3$ (18:1)
Palmitic: R= - $(CH_2)_{14}{-}CH_3$ (16:0)
Stearic: R= - $(CH_2)_{16} – CH_3$ (18:0)
Linoleic: R = - $(CH_2)_7$ CH=CH- CH_2- CH=CH $(CH_2)_4CH_3$ (18:2)
Note: the ratio represents the number of carbon atoms to the double bonds present in the chains.
Percentages of each fatty acid chain present in common oils and fats are shown in table 1.

BIODIESEL FEEDSTOCKS
The biodiesel feedstocks are classified into three based on their fatty acid content as follows:
1. Very low free fatty acid or Refined grade oils (FFA < 1.5%).
2. Low free fatty acid (FFA < 4%).
3. High free fatty acid (FFA ≥ 20%).

Other potential feedstocks include; acid oil, fatty acid and trap grease whose FFA > 50%.

BIODIESEL PRODUCTION TECHNOLOGY

Biodiesel production technology can be grouped as

- Base catalyzed transesterification with refined oils
- Acid esterification followed by transesterification of low or high free fatty acid greases and fats.

The core process of most biodiesel production is transesterification. In this process, animal fat or vegetable oil consisting mostly of triglycerides is reacted with a catalyst and alcohol. The reaction consumes the triglycerides and liberates glycerols and alkyl esters of lower alcohols.

Equation for the reaction is as shown in fig 2;

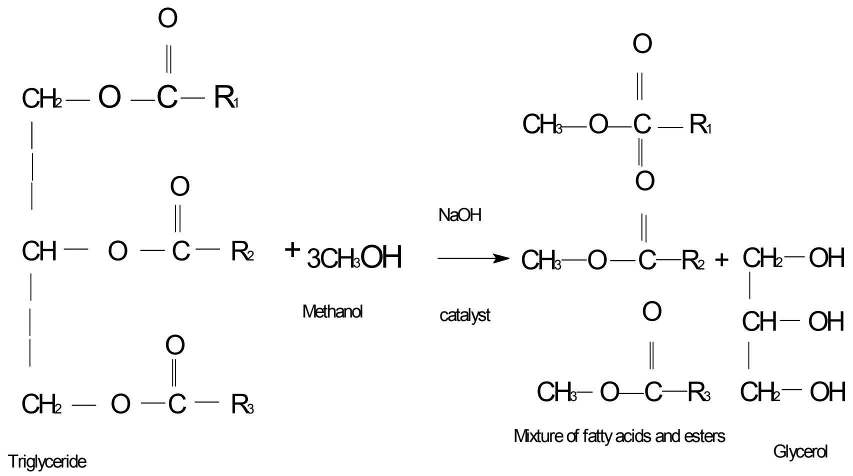

Fig 2: Trans esterification Reaction; R_1, R_2 , and R_3 are fatty acid chains

The goal of all the technologies is to produce a fuel grade biodiesel whose properties meet ASTM D – 6751, EN 14214 and IS 15607 standard. The quality control measure involves the complete removal of alcohol, catalyst, water, soaps, glycerine, and unreacted triglycerides and free fatty acids. The failure of the quality control measures causes the methyl ester product to fail one or more fuel standards.

Production of biodiesel can be run as batch or continuous processes. Batch processes provide excellent opportunities for quality control.

Base catalyzed transesterification using refined oils has high efficiencies up to 99.9% and produces good fuels after removing excess methanol, base catalyst, and glycerine.

Table 2 and 3 shows the typical input and output stream of the production process respectively.

POLLUTION

As biodiesel becomes more widely used, it is important to consider how consumption effects environment.

In the United States, biodiesel is the only alternative fuel to have successfully completed the Health Effects Testing requirements (Tier I and Tier II) of the Clean Air Act (1990). Biodiesel can reduce the direct tailpipe-emission of small particles of solid combustion products, on vehicles with particulate filters by as much as 20 percent compared with low-sulfur (< 50 ppm) diesel. Particulate emissions as the result of production are reduced by around 50% compared with fossil-sourced diesel. *(*en.wikipedia.org*)*. Biodiesel has a higher octane rating than petrodiesel, which can improve performance and clean up emissions compared to crude petro-diesel (with octane rating lower than 40%).

Research examining the biodegradability of different biodiesel fuels found that all of the biofuels studied (including Neat Rapeseed oil, Neat Soybean oil, and their modified ester products) were "readily biodegradable" compounds, and had a relatively high biodegradation rate in water (Zhang , et.al, 1998). Additionally, the presence of biodiesel can increase the rate of diesel biodegradation via co-metabolism. As the ratio of biodiesel is increased in biodiesel/diesel mixtures, the faster the diesel is degraded. Another study using controlled experimental conditions also showed that fatty acid methyl esters, the primary molecules in biodiesel, degraded much faster than petroleum diesel in sea water (DeMello, et.al, 2007).

ADVANTAGES OF BIOFUELS OVER FOSSIL FUELS.

There are many advantages of biofuels over fossil fuels that make the alternative fuel source an attractive option presently and in the future. With the awareness of global warming going around the world, biofuel productions have really begun to take off. Some of the benefits of biofuels over fossil fuels include;

- **Renewable:** Biofuels are made from organic materials, and even organic waste, there is practically an infinite amount of biofuels available. We don't need to lose energy getting rid of our waste, but reverse the process and make sure we get all the energy out of it. This may be one of the biggest reasons that biofuels are getting more popularity.

- **Lower emissions:** Fossil fuels give off toxic emissions. These pollutants, called greenhouse gases, trap the sun rays inside our atmosphere and has been linked with ozone layer depletion. This causes global warming. Biofuels do not release as much carbon as fossil fuels do, and because of this, there are fewer harmful emissions out of biofuels.
- **Safer.** Finding these fossil fuels in the earth is dangerous as a result of accidents associated with their exploration. There are drilling, mining, and other activities that are done to get to traditional oil reserves and then refining. There is not as much danger when you just need to grow the biofuels on a farm.
- **Biodegradable.** Biofuels are made out of organic substances, which are biodegradable. These fuels are much less toxic in the event occurances like the oil spills that occur in the Gulf of Mexico. These spills are made worse due to the fact that it is oil. If these spills were of biofuels, they would break down naturally, and the environment would not be affected nearly as much.

CONCLUSION

Biodiesel no doubt has the potential of reducing emission of toxic wastes into the atmosphere. Its production will go a long way into reducing over dependence on fossil fuels. The net result of biodiesel production will ultimately create a safe environment, increased agricultural production and a balance of trade among nations.

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Table 1: Percentages of each fatty acid chain present in common oils and fats

Oil or fat	14:0	16:0	18:0	18:1	18:2	18:3	20:0	22:1
Soyabean		6 - 10	2 – 5	20 – 30	30 – 60	5 – 11		
Corn	1 – 2	8 – 12	2 – 5	19 – 49	34 – 62	Trace		
Peanut		8 – 9	2 – 3	50 – 65	20 – 30			
Olive		9 – 10	2 – 3	73 – 84	10 – 12	Trace		
Butter	7 – 10	24 - 26	10 – 13	28 – 31	1 – 2.5	0.2 – 0.5		
Lard	1 – 2	28 – 30	12 – 18	40 – 50	7 – 13	0 – 1		
Tallow	3 – 6	24 – 32	20 – 25	37 – 43	2 – 3			
Linseed oil		4 – 7	2 – 4	25 – 40	35 – 40	25 – 60		

Table 2: Input Streams of production

Refined oil	1000kg
Methanol	107kg
KOH 88%	10kg
Acids(acetic HCL Sulphuric)	8kg
Water	17kg
Electricity	20kwh

Table 3: output streams of production.

Biodiesel	1000kg
Glycerine 88%	125kg
Fertilizer	23kg
By product chemicals	Nil